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#239 APRIL 2025

Sky at Night

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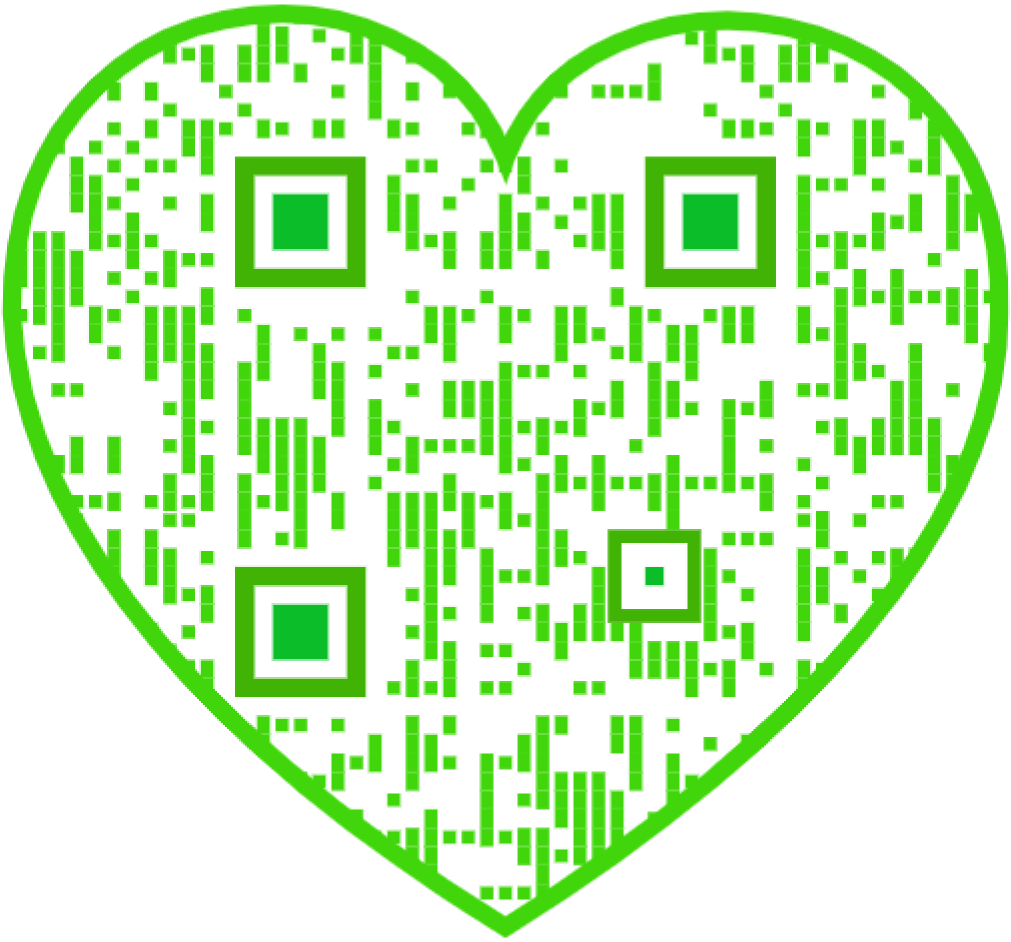

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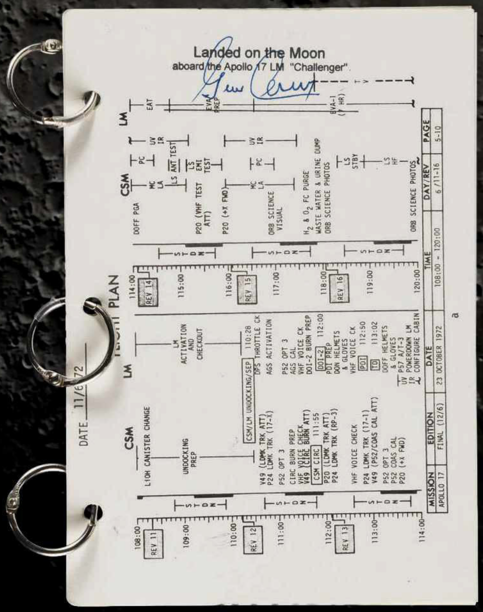

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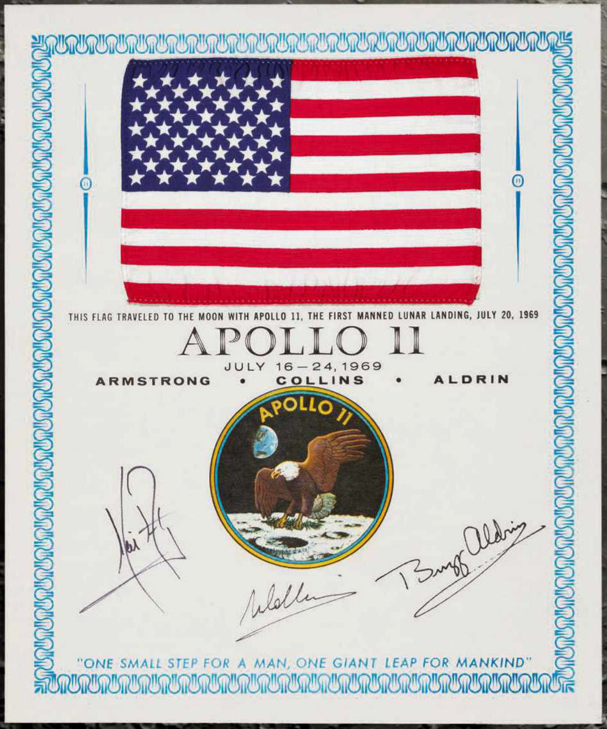

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Welcome

To the telescopes! Get ready for springtime galaxies galore

We love galaxy season here at *Sky at Night Magazine*, that time of year when the tilt of Earth's axis on its orbit around the Sun places a particularly galaxy-rich region of space in a prime viewing location. Messier 99, 'St Catherine's Wheel', the galaxy featured on our cover, is one of the estimated 2,000 members of this Realm of the Galaxies. It's this area, centred on the constellation of Virgo, that expert Alabama stargazer Rod Mollise explores in his feature. Turn to **page 28** to discover some of the finest galaxies a telescope can be pointed at, as well as his tested deep-sky observing tips.

It just so happens that we're testing some kit this month that promises an easier way to view objects like St Catherine's Wheel: the Dwarf 3 smart telescope. Because smart scopes deliver images to a screen, they have the crucial advantage of astrophotography built-in: image stacking. This means they can produce sharp, bright pictures of faint, far-off galaxies on a smartphone or tablet in real time, with real ease, potentially opening up technically tricky areas of telescope observing to newcomers. Turn to our First Light review on **page 86** to find out how the Dwarf 3 fared in our deep-sky tests.

If indeed you are a newcomer to the night sky, do take a look at a few of our top observing picks in the Sky Guide this month as well. There's a particularly pleasing meet-up between the waxing crescent Moon and the easy-to-find Pleiades star cluster, and a meteor shower peaking while the sky is unspoilt by bright moonlight.

Clear skies, and enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Tuesday 22 April.

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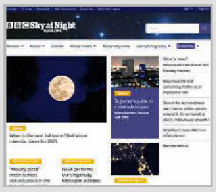
Sky at Night – lots of ways to enjoy the night sky...

Television

Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18



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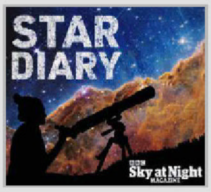

Podcasts

Discover the best things to see in the night sky every week by listening to our Star Diary podcast

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Get each month's issue on your Apple or Android device, now with bonus image galleries

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The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

Find out more at: www.skyatnightmagazine.com

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Ⓒ = on the cover

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The Sky Guide

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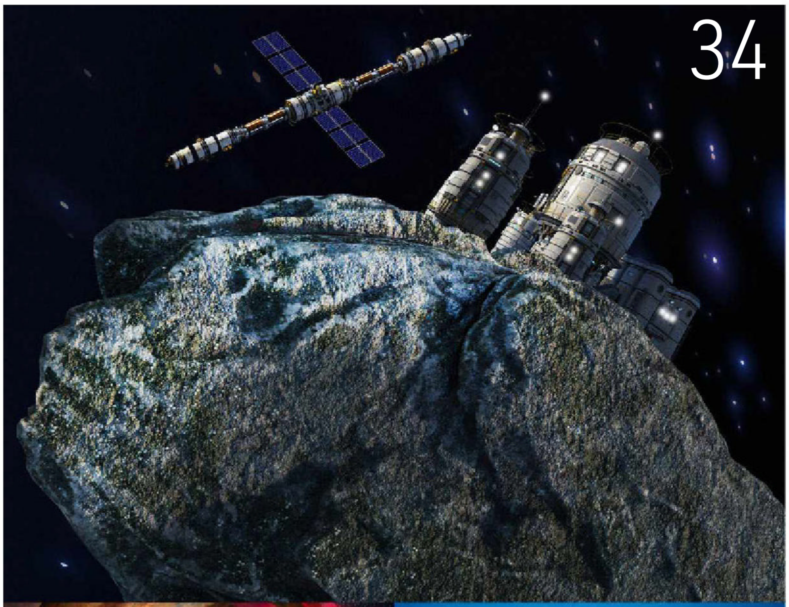
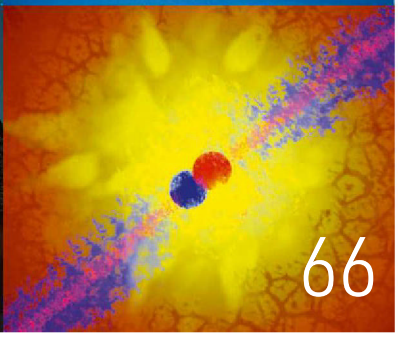
COVER IMAGE: ESA/HUBBLE & NASA/M. KASLIWAL/J. LEE AND THE PHANGS-HST TEAM. THIS PAGE: TOMMY NAWRATIL/ CCDGUIDE.COM, VICTOR HABBICK VISIONS/SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO, NASA/JPL-CALTECH, @THESHED_PHOTOSTUDIO, CAVAN IMAGES/ALAMY STOCK PHOTO, JAPATINO/GETTY, DOTTEDHIPPO/GETTY

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

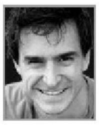




This month's contributors

Lewis Dartnell

Astrobiologist



"I'm fascinated by the prospect of oceans of liquid water laying hidden beneath the surfaces of icy moons. Just imagine scuba diving adventures in the future!" **Join Lewis as he looks under the ice on page 40**

Stephen Ramsden

Solar observer

"Want to see a star up close? With the Sun currently active, now's a great time to get into solar observing. It's safe and suitable even for complete beginners." **Stephen shares his passion for the Sun on page 60**

Katie Sawers

Science writer

"The strange physics of black holes is what first drew me to astronomy – objects still shrouded in mystery and so dense they warp space and time around them." **Learn more about the secrets of black holes on page 72**

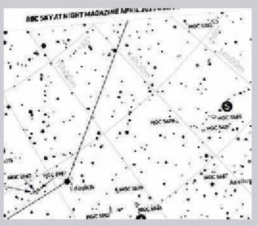
FREE BONUS CONTENT

Find it at **www.skyatnightmagazine.com/bonus-content**

APRIL HIGHLIGHTS

Will we find life beyond Earth?

Astrobiologist Lisa Kaltenegger gives her thoughts on one of the biggest unanswered questions of our time.



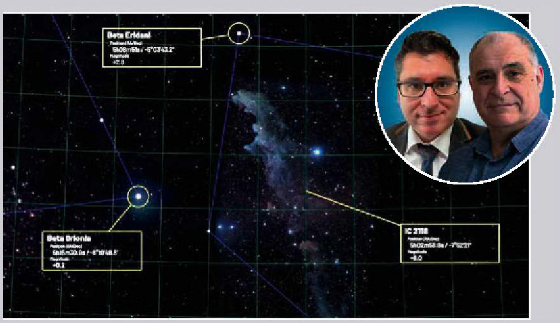
Binocular and deep-sky tours

Download and print off charts to help you find some of the best deep-sky targets listed in this month's Sky Guide.

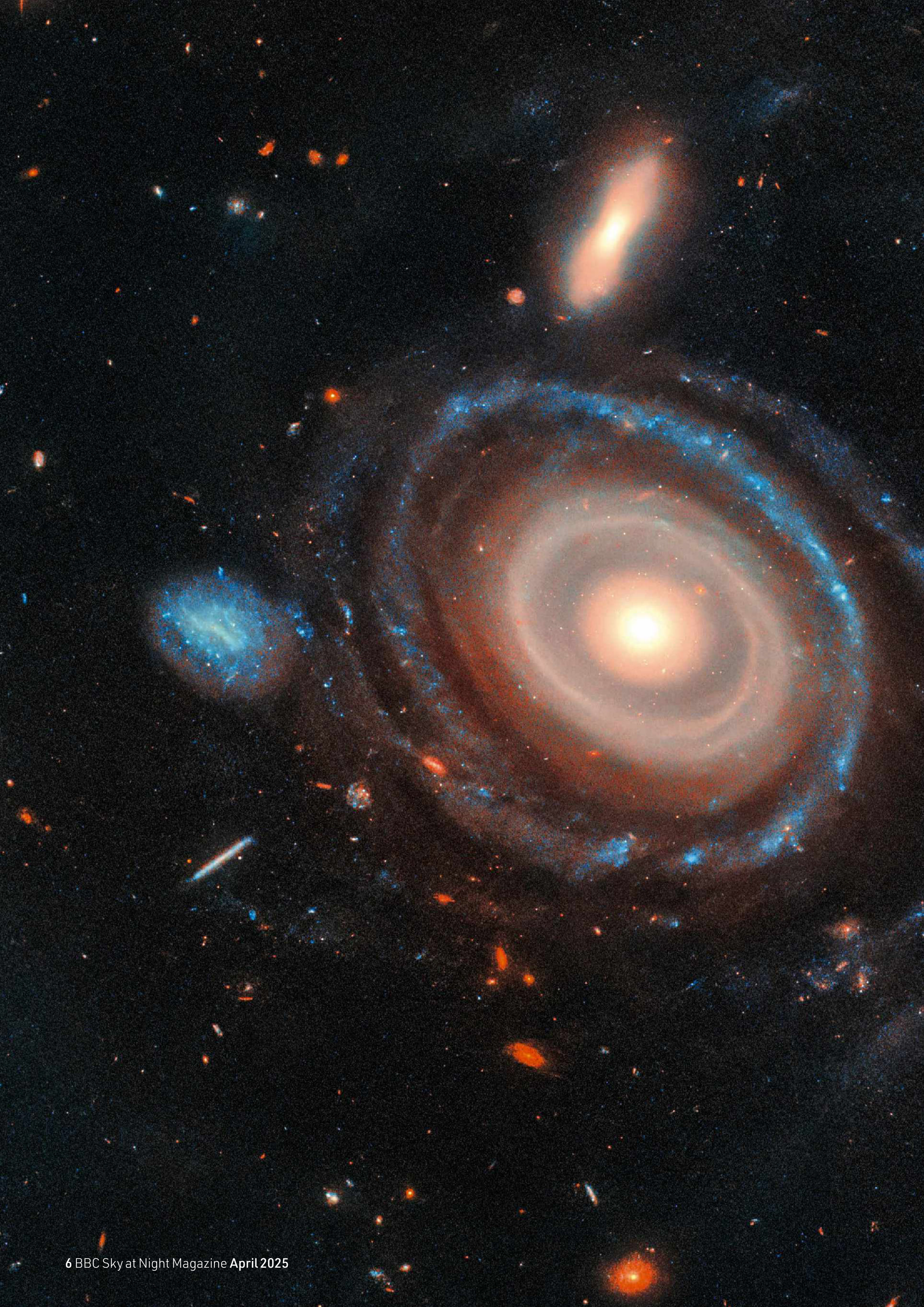
Extended astro image galleries

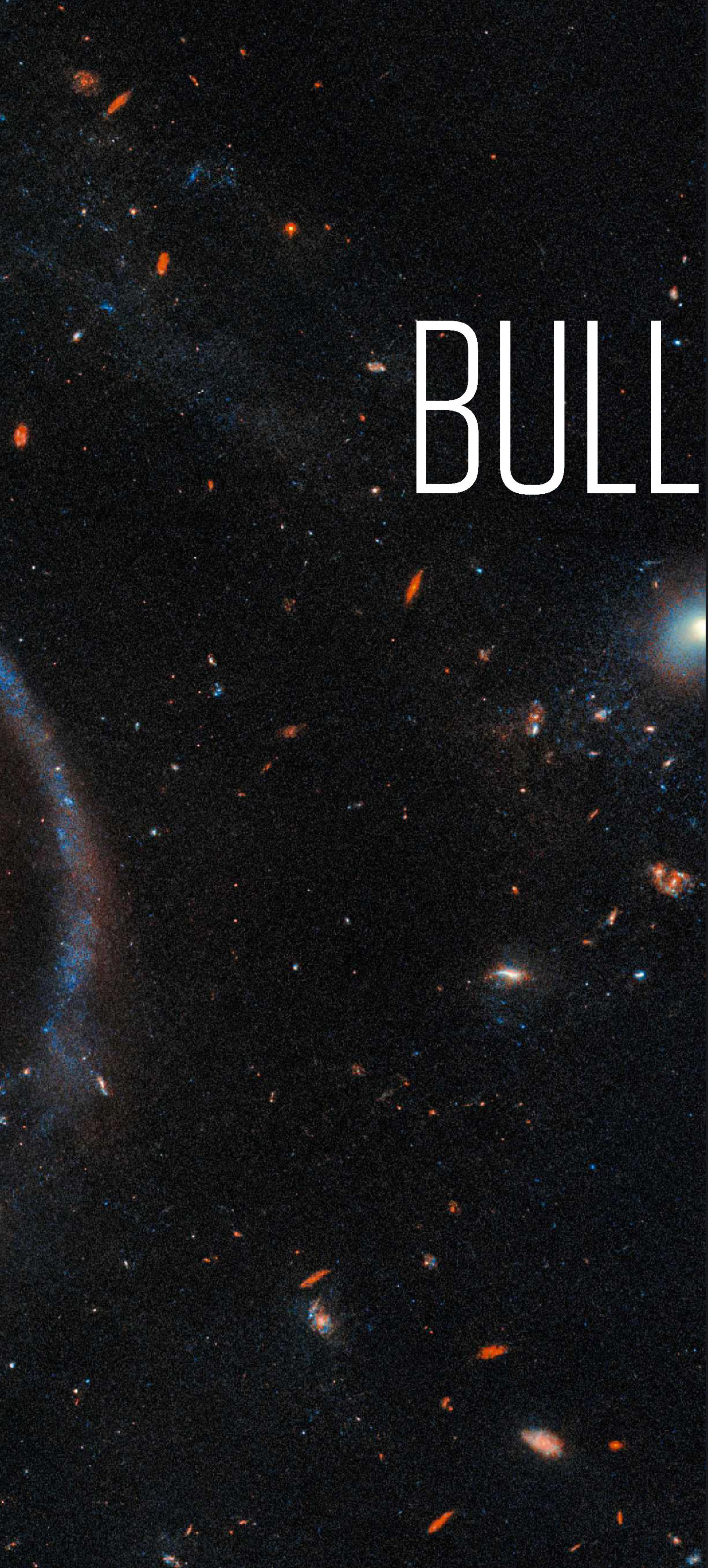
Amazing images of the cosmos by professional telescopes, spacecraft and *BBC Sky at Night Magazine* readers.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.





BULLSEYE!

A dust-up with a neighbour left this one-of-a-kind galaxy with nine rings

HUBBLE SPACE TELESCOPE, 4 FEBRUARY 2025

This is LEDA 1313424, a spiral galaxy that's around 2.5 times larger than our own Milky Way. Uniquely, LEDA 1313424 has nine rings, where other spiral galaxies have a maximum of three – giving the object its nickname, the Bullseye Galaxy. That's because, around 50 million years ago, the blue dwarf galaxy seen to LEDA 1313424's immediate left passed right through its larger neighbour. This extremely rare event sent waves of material flying both inwards and outwards, which then coalesced into the series of concentric rings seen today.

NASA/ESA/IMAD PASHA (YALE) PIETER VAN DOKKUM (YALE)

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Explore a gallery of these and more stunning space images
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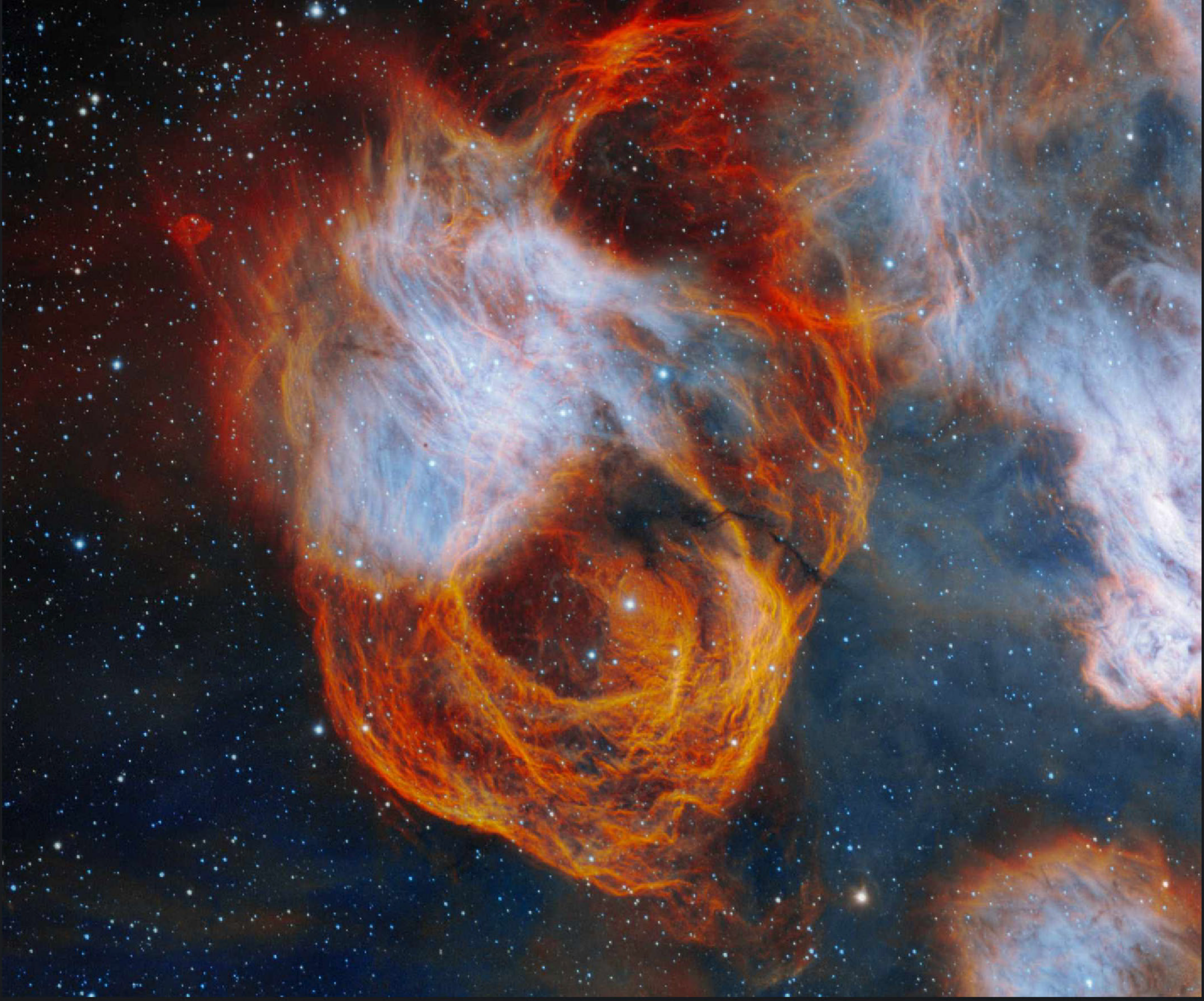
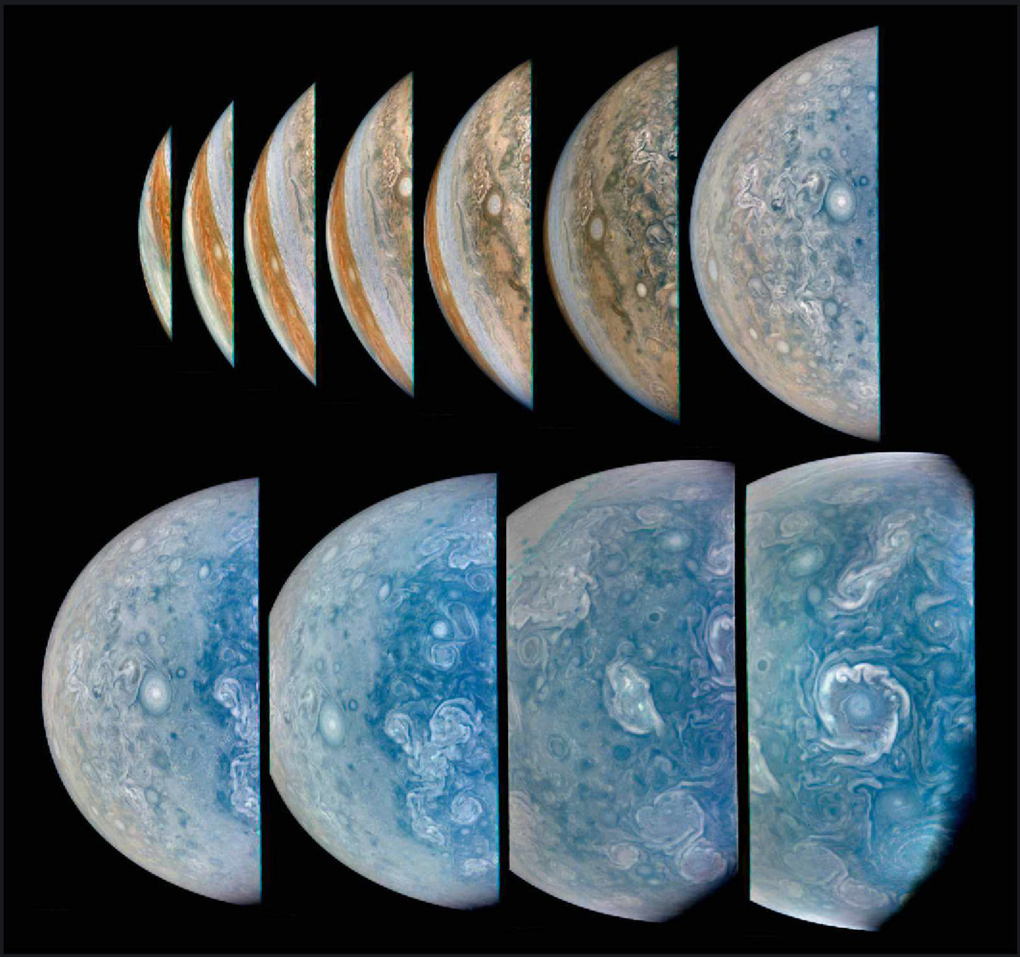


△ Coming up roses

GEMINI SOUTH, 14 FEBRUARY 2025

Open cluster NGC 2040 here reveals its surrounding nebulosity as never before. Reds and oranges in this picture denote hydrogen-rich regions, light blues denote oxygen-rich regions, while white regions are rich in both. The result looks not unlike a rose, which is why NOIRLab released the image on Valentine's Day!



Skimming the cyclones ▷

JUNO, 27 JANUARY 2025

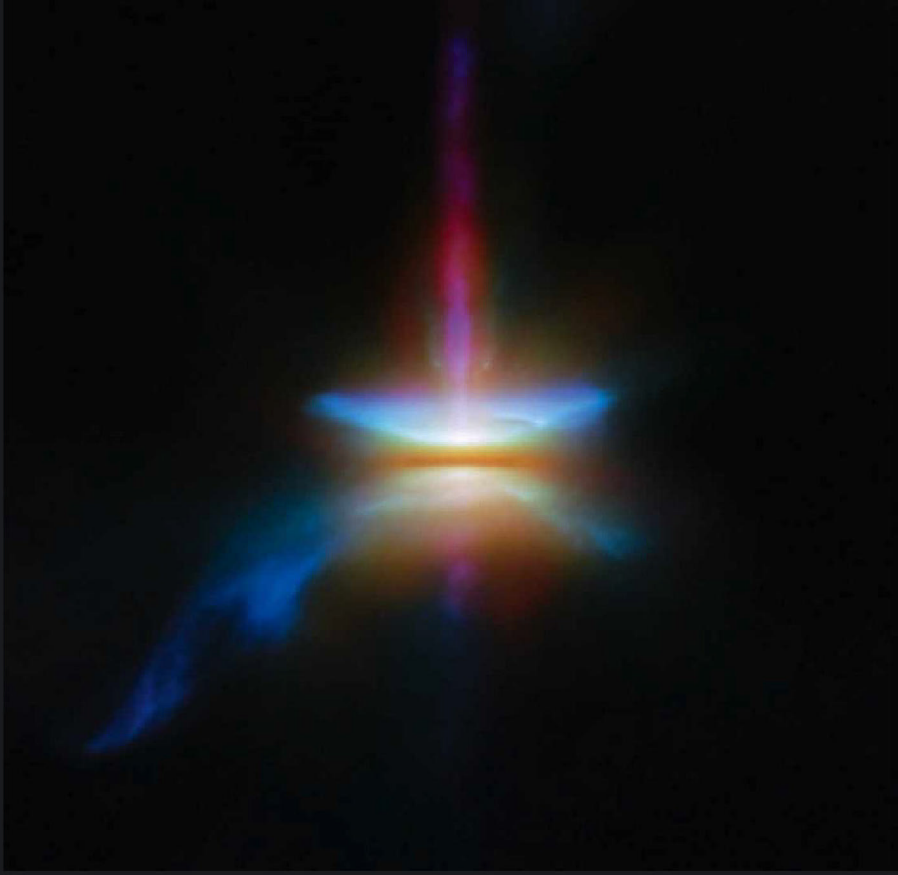
Giant cyclones rage over Jupiter's northern polar regions in a composite image created using data captured by the JunoCAM instrument on board NASA's Juno spacecraft. Juno spied the storms when it made its 65th close fly-by of the gas giant in September 2024.

INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA. IMAGE PROCESSING: J. MILLER & M. RODRIGUEZ (INTERNATIONAL GEMINI OBSERVATORY/NSF NOIRLAB) T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF NOIRLAB) M. ZAMANI (NSF NOIRLAB), NASA/JPL-CALTECH/SWRI/MSSS/IMAGE PROCESSING BY BRIAN SWIFT © CC BY, ESA/WEBB/NASA & CSA/TAZAKI ET AL, NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA

Jet engine ▷

JAMES WEBB SPACE TELESCOPE, 4 FEBRUARY 2025

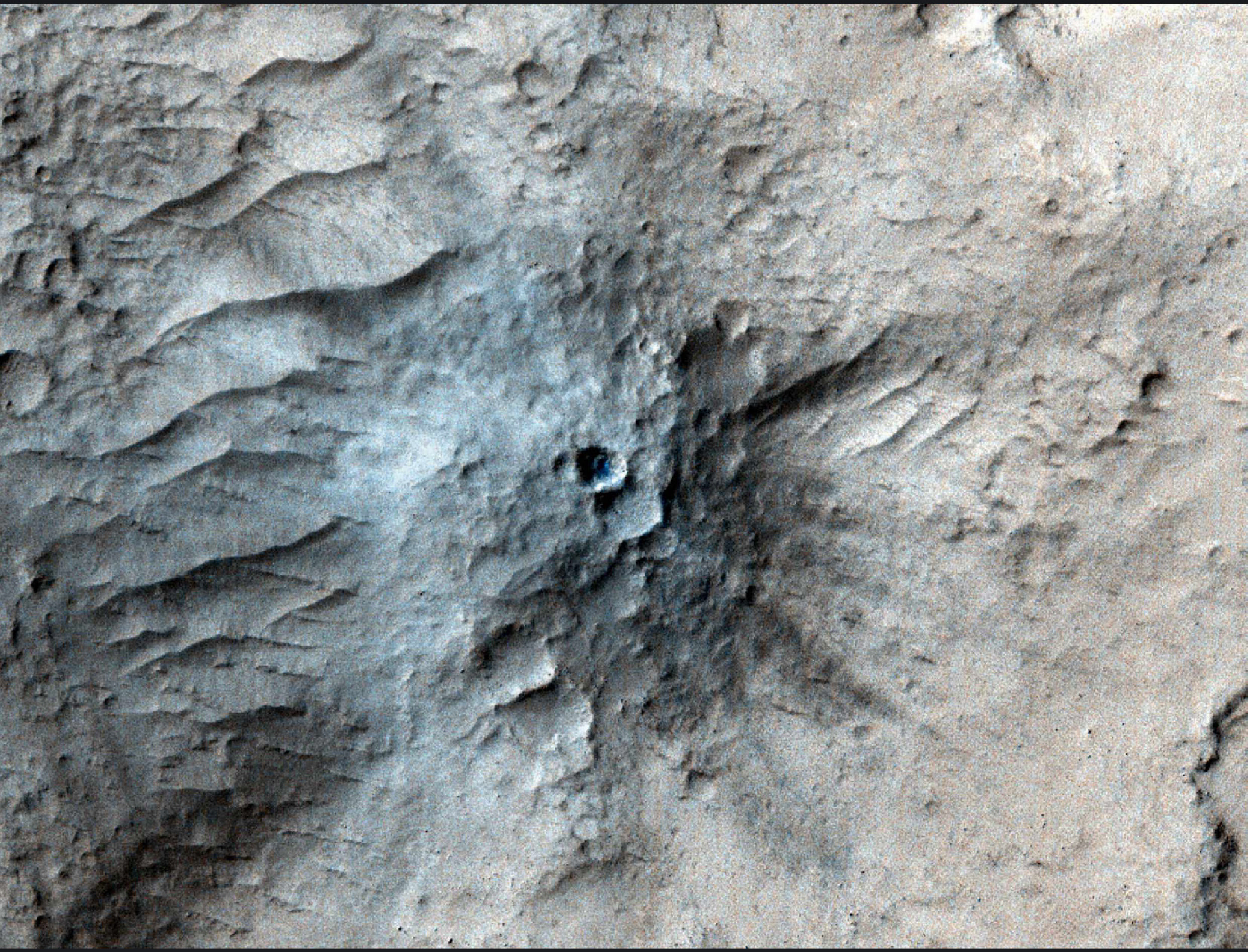
HH 30 is a small region of nebulosity in the star-forming Taurus Molecular Cloud. The dark band across its centre is a protoplanetary disc – seen side-on and obscuring its central star – while the colourful jets above and below it are outflows of gas from young stars, heated into luminescence by shockwaves.



▽ From quake to crater

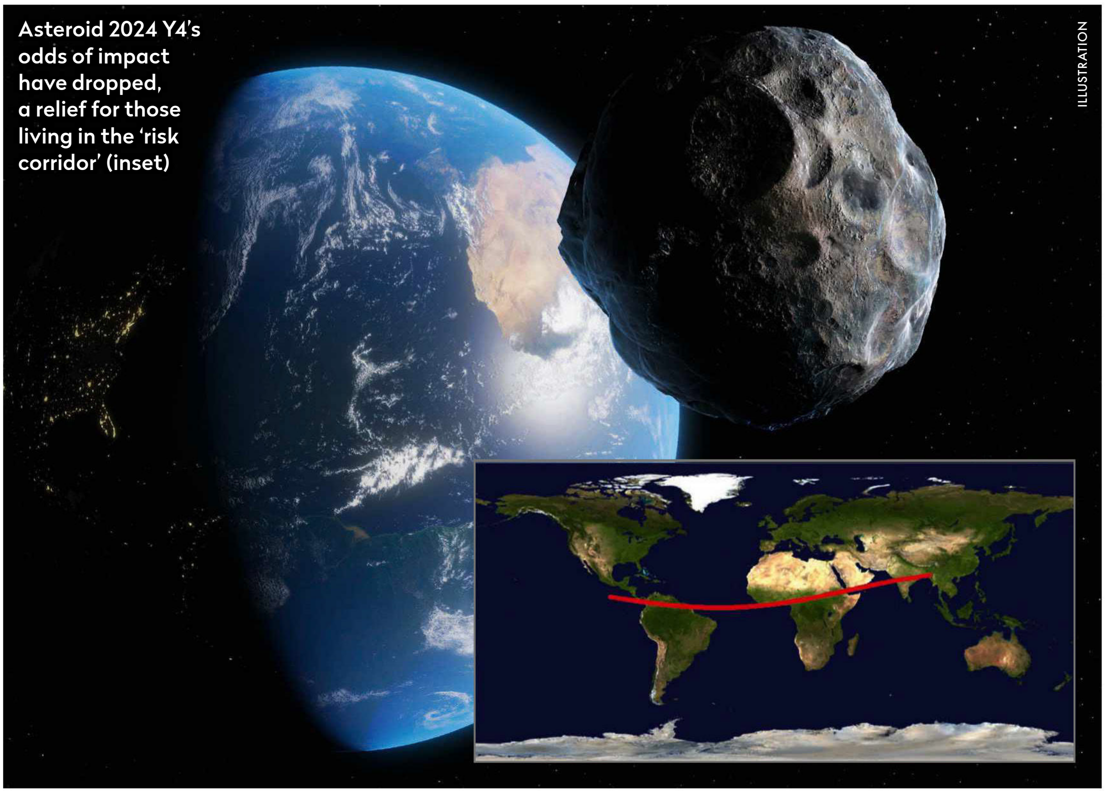
MARS RECONNAISSANCE ORBITER, 3 FEBRUARY 2025

This crater was the result of a meteor or asteroid impact in Mars's Cerberus Fossae region in 2021. After the now-defunct InSight lander detected seismic waves from the impact, NASA used AI to scan MRO images for new craters, finding 123 that were analysed – first by machine learning, then by humans – to pinpoint the exact crater in question. See page 14 for more details.



The latest astronomy and space news, written by Ezzy Pearson

BULLETIN



Asteroid 2024 Y4's odds of impact have dropped, a relief for those living in the 'risk corridor' (inset)

Narrow escape from a 'city-killer' asteroid

The close call shows Earth is ready should another space rock approach

The sighting of a dangerous asteroid on a potential collision course with Earth has triggered planetary defence response procedures for the first time ever. Fortunately, the process successfully tracked the asteroid to reveal it will almost certainly miss Earth.

Asteroid 2024 YR4, discovered in December 2024, is estimated to be 40–90 metres in diameter. When astronomers realised the danger, they mounted an observing campaign to measure its orbit and more accurately gauge whether it would impact Earth. The probability of impact with Earth fluctuated as more measurements came in, reaching as high as 3.1 per cent.

That put the space rock at a three out of 10 on the Torino scale, which measures the danger of potential impacts – only asteroid Apophis has been rated more highly. The scale combines both the destructive potential of the asteroid and its probability of hitting Earth. Humanity can breathe a sigh of relief, however, as further orbit measurements soon dropped the impact chance to almost zero per cent.

Astronomers will continue to measure YR4's trajectory before it travels too far from Earth in its current orbit. Even the James Webb Space Telescope (JWST) will be put to work, making observations in March and May. There will be another chance to observe the asteroid when it circles back towards Earth again in 2028, before the potentially hazardous pass in 2032.

Had YR4 been on a collision course with Earth, it would have been large enough to destroy a city. The 'risk corridor' passed over regions of South America, Africa, India and China, areas with an estimated population of 100 million people. If the asteroid had been headed for a populated area, authorities may have attempted to deflect it. NASA proved this can be done with the DART mission, which altered the path of asteroid Dimorphos in 2022.

Though YR4 was a close call, it's a timely reminder of the danger asteroids pose to our planet. **cneos.jpl.nasa.gov**

MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY, DANIEL BAMBERGER/
WIKIMEDIA COMMONS, ESA/GAIA/DPAC/M. MARCUSSEN, DIMA_ZEL/GETTY

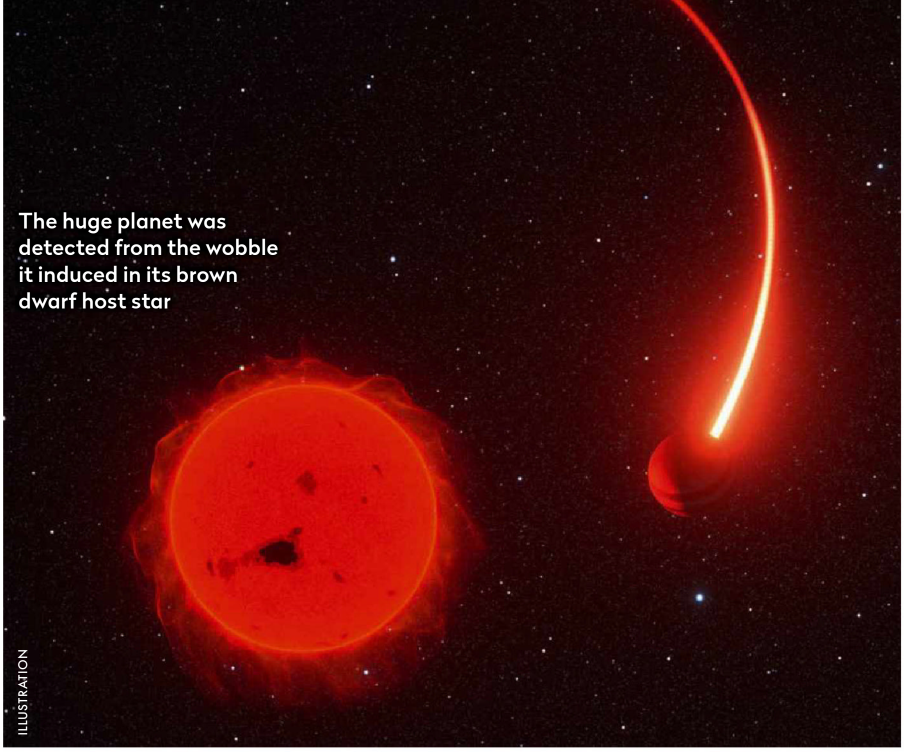
Comment

by Chris Lintott

If you're worried: relax. Rather than causing undue alarm, knowing there's a small chance 2024 YR4 might hit us is a sign of success. The threatening rock is probably no larger than a jumbo jet and yet we have spotted it many years before it might pose a threat. When the last thing this size hit Earth, most likely in Tunguska, Siberia in 1908, we had no idea it was coming until several miles of pine forest had a very bad day.

Soon, most things the size of 2024 YR4 will be routinely tracked, and missions like DART can defend us if needed. For the first time in human history, we have the knowledge and the techniques to defend against this threat from the skies.

Chris Lintott co-presents *The Sky at Night*


The huge planet was detected from the wobble it induced in its brown dwarf host star

Gaia uncovers its first exoplanet

Thousands more could be hiding in the retired craft's data

A giant planet just 244 lightyears from Earth has been uncovered within data gathered by the Gaia satellite. The discovery of Gaia-4b marks the first time the spacecraft's data has been solely responsible for an exoplanet discovery.

Gaia ended its scientific operations in January 2025, but its data will still be analysed for years to come. For a decade, the craft has monitored the positions of billions of bright stars, a technique called astrometry. For stars in our local cosmic neighbourhood, the measurements were accurate enough to detect the stellar 'wobble' created by the gravitational pull of an orbiting planet, which makes the star appear to move across the sky with a corkscrew motion. There are many stars that show such motion, but Gaia-4b is the first to be confirmed as an exoplanet.

"Gaia-4b is about 12 times more massive than Jupiter," says Guðmundur Stefánsson from the University of Amsterdam, the Netherlands, who led the study. "With an orbital period of 570 days, it is a relatively cold gas giant planet."

This orbit means it must be orbiting far away from its star. The star also has a low mass, around 0.6 times that of our Sun.

"Massive planets around low-mass stars are known to be relatively rare, but when they occur, they cause a larger wobble and therefore a stronger astrometric signature that is easier to detect," says Guðmundur.

Most known exoplanets were discovered using the transit technique, which relies on the shadow of a planet passing its host star for identification and which preferentially finds planets in close orbits. There could be thousands of exoplanets in more distant orbits to be discovered in the Gaia data and uncovering them over the coming years will help build a full picture of what other planetary systems exist.

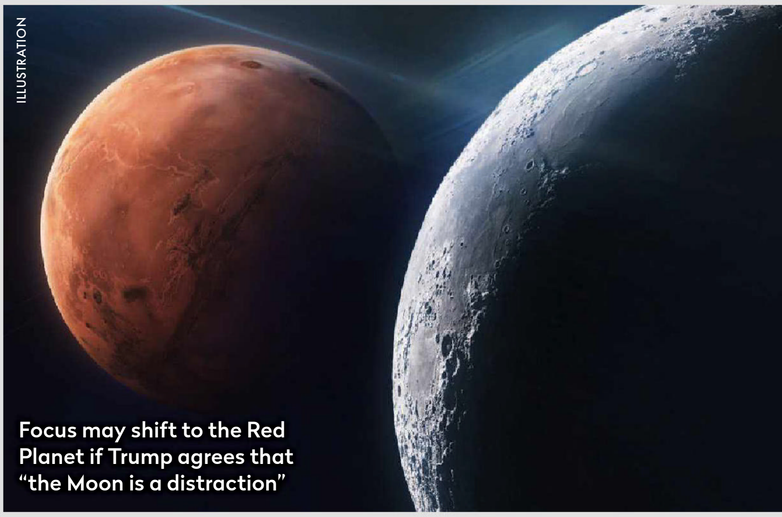
www.esa.int

Will Trump pivot NASA to Mars?

Scrutiny of the agency has put the future of the Artemis programme in doubt

President Donald Trump looks set to make sweeping changes at NASA, potentially changing track from landing on the Moon to Mars. In his inaugural address, Trump stated: "We will pursue our Manifest Destiny to the stars, launching American astronauts to plant the Stars and Stripes on the planet Mars." The announcement left many wondering if the Artemis programme, which aims to put the first woman on the Moon, but has been plagued by cost overruns and delays, could soon be on the chopping block.

As of the time of writing, no official statement had been given about the future of the Artemis programme. In early February, NASA's acting administrator Janet Petro confirmed that members of the Department of Government Efficiency had arrived at NASA and were in the process of auditing the agency. The department is led by Elon Musk, CEO of spaceflight company SpaceX, who has long been a critic of the $93-billion Artemis programme. Musk has previously stated that "the Moon is a distraction" and suggested refocusing on Mars.



Focus may shift to the Red Planet if Trump agrees that "the Moon is a distraction"

The Artemis programme is not without supporters, however. There are many members of Congress – which ultimately controls NASA's budget – whose constituencies stand to gain thousands of jobs supporting the Artemis programme. Other members of Congress have expressed concerns that Musk has a clear conflict of interest, as his company SpaceX has billions of dollars' worth of contracts with NASA.

ILLUSTRATION

Finding alien life could get a boost from the test, which proved that bacteria swim towards the amino acid L-serine

Researchers uncover how to get alien life moving

A new test could search for life by making Mars microbes move

Movement is often one of the clearest signs of whether something is alive or not. Taking advantage of this, a new test which prompts microbes to move could be adapted into a novel way to hunt for life on other planets.

The test uses a chemical called L-serine, which is one of the amino acids on which all Earth life is based. Scientists placed this chemical next to three different organisms and found that they all moved towards the L-serine.

"This movement, known as chemotaxis, could be a strong indicator of life and could guide space missions looking for living organisms on Mars or other planets," says Max Riekeles of the Technical University of Berlin, who led the study.

L-serine is known to inspire movement in a wide variety of organisms, but for this test the team chose three extremophiles – microbes well used to surviving in extreme conditions. Two were bacteria: Bacillus subtilis, which can survive up to 100°C (212°F), and Pseudoalteromonas haloplanktis, which thrives even at sub-zero temperatures. The third microbe was Haloferax volcanii, an archaea, which are superficially similar to bacteria but evolutionarily very distinct in many key ways. This particular archaea typically lives in high-salinity environments, similar to what is found on Mars.

"Bacteria and archaea are two of the oldest forms of life on Earth, but they move in different ways and evolved motility systems independently from each other," says Riekeles. "By testing both groups, we can make life-detection methods more reliable for space missions. Since Haloferax volcanii thrives in extreme salty environments, it could be a good model for the kinds of life we might find on Mars."

The test involves a simple method to look for signs of chemotaxis, using a special slide featuring two chambers, separated by a semi-permeable membrane. The microbes were placed on one side, the amino acid on the other and then observed under a microscope.

"If the microbes are alive and able to move, they swim toward the L-serine through the membrane," says Riekeles. "This approach could make life detection cheaper and faster, helping future missions achieve more with fewer resources. It could be a simple way to look for life on future Mars missions."

www.frontiersin.org

CAVAN IMAGES/GETTY, ALEJANDRO BENITEZ-LLAMBAY/UNIVERSITÄT MAILAND-BICOCCA/MPA, JOSEPH DEPASQUALE/SPACE TELESCOPE SCIENCE INSTITUTE

A strand of the cosmic web

Filament picture shows part of the structure that underpins the whole Universe

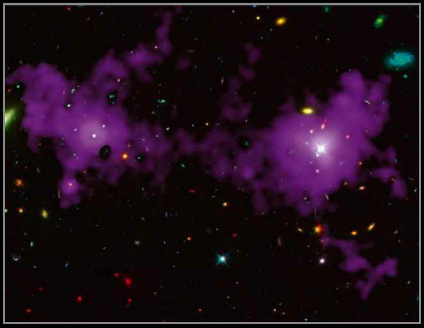
After hundreds of hours of observing time with the Very Large Telescope at the European Southern Observatory in Chile, a team of astronomers have managed to create the most detailed image ever of one single filament of gas connecting galaxies together (shown in purple, below).

The cosmos is strung together by these tenuous filaments of gas that, combined, form an interconnected mesh known as the 'cosmic web' which funnels gas between galaxies and provides the scaffolding on which our Universe is built.

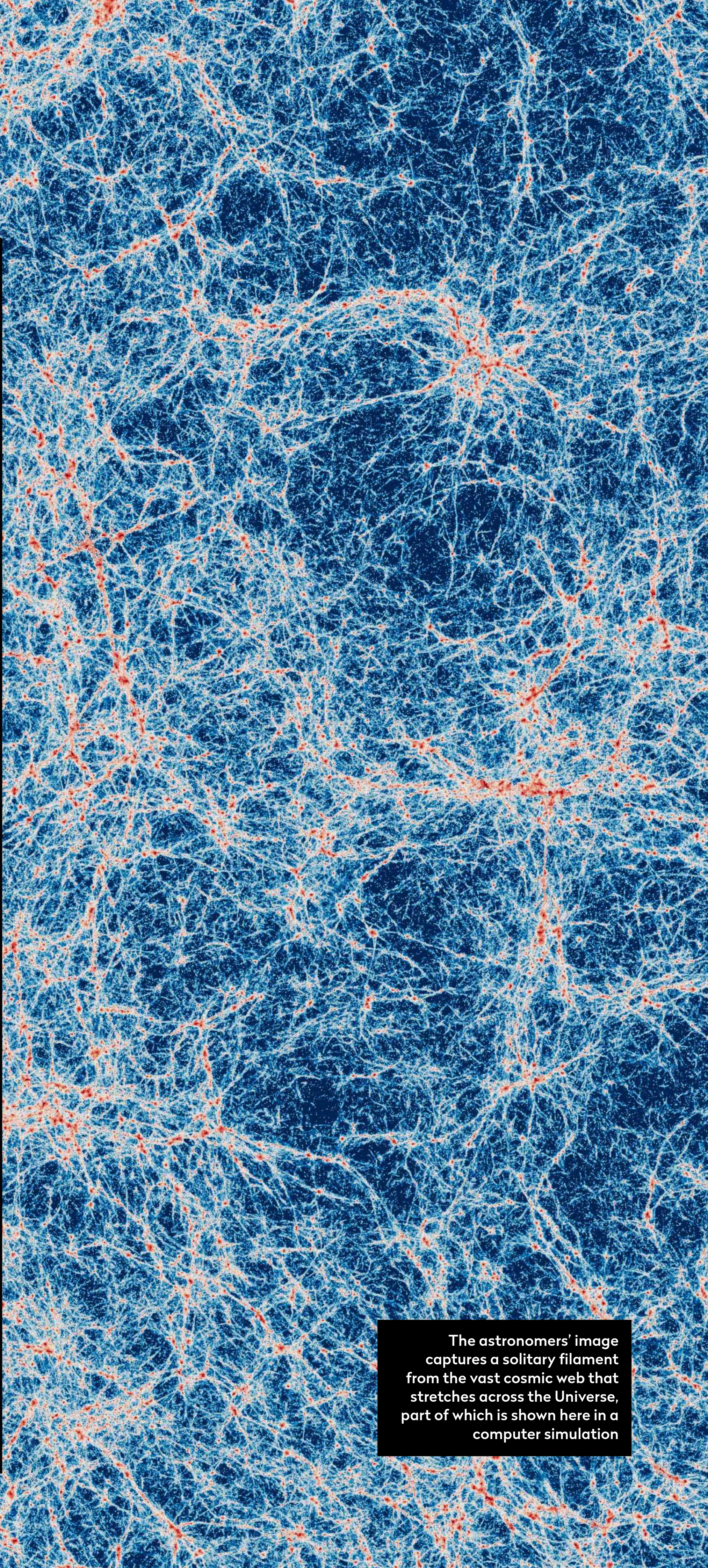
These filaments are extremely difficult to capture, as they're incredibly dim, but the light from the filament stretches three million lightyears between two actively growing galaxies.

"By capturing the faint light emitted by this filament, which travelled for just under 12 billion years to reach Earth, we were able to precisely characterise its shape," explains Davide Tornotti. "For the first time, we could trace the boundary between the gas residing in galaxies and the material contained within the cosmic web through direct measurements."

www.mpg.de



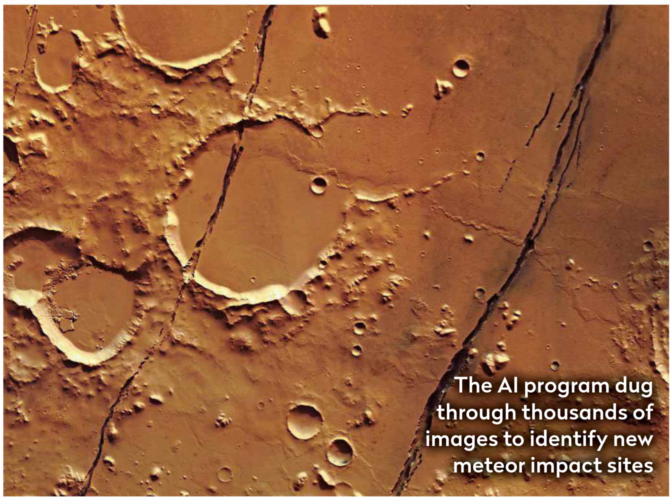
▲ The direct high-definition image shows a single filamentary structure connecting two active galaxies



The astronomers' image captures a solitary filament from the vast cosmic web that stretches across the Universe, part of which is shown here in a computer simulation

Martian meteors go deeper than expected

AI leads astronomers to a fresh Mars impact that shook the planet's deep mantle



The AI program dug through thousands of images to identify new meteor impact sites

Meteor strikes impacting the surface of Mars could shake the Red Planet far more deeply than previously thought. The revelation came after planetary geologists used a new AI algorithm to link the appearance of new impact craters in images from the Mars Reconnaissance Orbiter (MRO) with seismic information from the InSight lander.

NASA's InSight lander spent four years on Mars listening out for 'marsquakes'. By the time it retired in 2022, it had discovered 1,300 such seismic events, many from meteor impacts. In some cases, astronomers were able to match these with recent impacts detected by the MRO. As MRO photographs the same areas over and over again, it's possible to find new craters by comparing old images with new ones. However, it would take a human many years to analyse the thousands of images, so the InSight team utilised an AI-driven program to speed up the job.

The program uncovered 123 craters, 49 of which were matched with marsquakes detected by InSight. Initially, the researchers focused on a 21.5-metre (71ft) crater in a region known as Cerberus Fossae. The team were surprised to find that the crater was 1,640km (1,019 miles) away from where InSight picked up the shock. The energy of the wave suggested the impact was much closer, as Mars's crust tends to dampen such waves. The further an energy wave travels through the crust, the weaker it gets, suggesting that this impact took a more direct route through the planet's mantle.

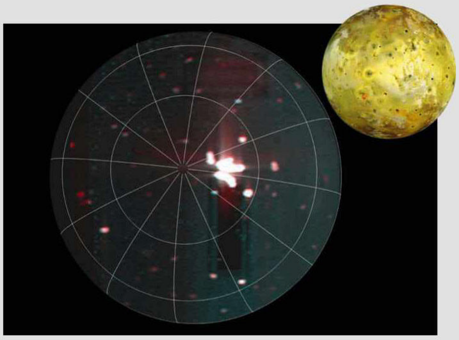
"We used to think the energy detected from the vast majority of seismic events was stuck travelling within the Martian crust," says Constantinos Charalambous from Imperial College London, who works on InSight. "This finding shows a deeper, faster path – call it a seismic highway – through the mantle, allowing quakes to reach more distant regions of the planet." **www.jpl.nasa.gov**

Eruptions on Io break records

The turbulent moon's new hot spot is five times larger than the previous record holder

Vast numbers of volcanoes have been spotted erupting from an area at the southern pole of Jupiter's moon Io. Picked up by NASA's Juno orbiter, the hot spot is the most powerful volcanic activity ever observed.

With over 400 known volcanoes across its surface, Io is the most volcanic world in our Solar System. Its extreme geology stems from its close and highly elliptical orbit around Jupiter. Taking just 42.5 hours to orbit, the gravitational tug of war between planet and moon squeezes the rock inside Io, with the resulting friction creates a huge amount of heat.



▲ The Lake-Superior-sized eruption near Io's south pole is the most powerful volcanic event ever recorded in the Solar System

Juno has regularly passed by this tortured moon since it arrived at Jupiter in 2016. During a fly-by on 27 December 2024, the spacecraft's instruments picked up a huge hot spot around the size of Lake Superior, the largest lake in the US. The energy being put out by the combined eruptions is six times greater than all the world's power plants. The December fly-by passed at a relatively distant 74,400km (46,200 miles), but a much closer pass occurred on 3 March, which researchers are now examining for signs of any changes to the landscape.

"This is the most powerful volcanic event ever recorded, on the most volcanic world in our Solar System – so that's really saying something," says Scott Bolton from the Southwest Research Institute and Juno's principal investigator. "The intriguing feature could improve our understanding of volcanism not only on Io but on other worlds as well." **www.jpl.nasa.gov**

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ZERO-G TEAM
esa
airZero

ESA para-astronaut John McFall during parabolic zero-gravity flight training in April 2023

John McFall cleared for takeoff

Astronauts with disabilities could one day fly on missions to the International Space Station

Former British Paralympian John McFall has taken one step closer to becoming the first astronaut with a disability to be eligible for flight missions, after being medically certified for long-duration spaceflights.

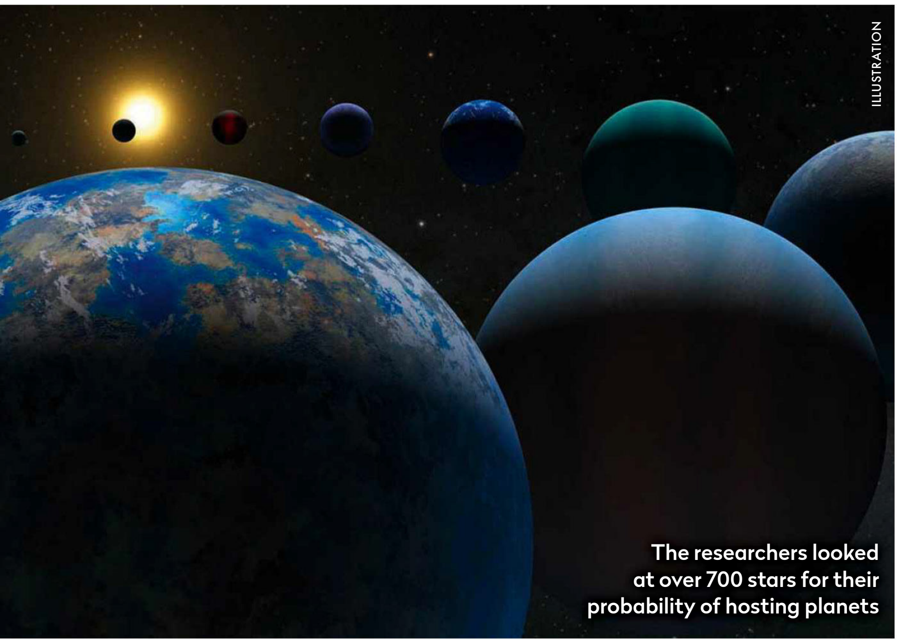
McFall, who has a prosthetic leg, helped the European Space Agency with their Fly! Feasibility study from 2022 to 2024. The study assessed the challenges barring people with disabilities from flying on the International Space Station, ultimately concluding that it's feasible for someone with certain physical disabilities to become a fully integrated crew member on the ISS.

"Now we're progressing to the next phase, and what we want to do is realise that opportunity to fly, so we're moving forward… into the Mission Ready phase," says McFall. "This phase will include looking at hardware certification and moving further down that process. One of the roles of an astronaut is to do important science in microgravity whilst working in space and it's really my hope that, if I get the chance to fly, we realise what we do in space – the things we learn, the problems we solve, the technology that we develop – has a trickle-down effect and benefits people here on Earth in wider society."

www.esa.int

Our experts examine the hottest new research

CUTTING EDGE



The researchers looked at over 700 stars for their probability of hosting planets

Finding the plum spot for planets

Our Milky Way's centre is your best bet as a cosmic holiday destination

As of this month, over 5,500 exoplanets have been discovered orbiting other stars in the Galaxy. This tells us that planet formation is a universal process across the Milky Way and the majority of stars probably have at least one planet. But before you plan an extraterrestrial trip, you'll want to pin down the best Galactic neighbourhood to visit. Not every planetary system looks the same: there are differences between the number of gas giant planets and lower-mass, mostly rocky worlds. So, where will you most likely find the kind of planet you're after?

The difference stems from how gas giants form through core accretion. First, a mass of rocky material and ice around 10 Earth masses in size clumps together. Then, the powerful gravity of this core pulls in a thick envelope of gas from the nebula from which both the planet and proto-star are born. So the birth of gas giant planets like Jupiter is dependent on there being sufficient rocky material within the solar nebula.

Stars, and the nebulae they are born from, are mostly composed of the lightest element, hydrogen, with a little helium mixed in. The cosmos also contains heavier elements which, somewhat confusingly, astronomers refer to as metals. The rocky material and ices needed to form the core of gas giants are made of these heavier elements, and astronomers have observed a direct relationship between the abundance of 'metals' in a star and the presence of giant planets.

Increase in metallicity

These heavier elements weren't present in the early Universe, but were forged by the first generations of stars exploding as supernovae. So metallicity has been increasing over time, and stars that formed closer to the centre of the Galaxy have a higher metallicity than those in the outer disc.

Joana Teixeira from the Institute of Astrophysics and Space Sciences at the University of Porto, Portugal, and her colleagues have been studying planet formation across the Galaxy. They wanted to find out how the age of different stars, and how near to the Galactic centre they formed, affect the kinds of planets they have. They took data from catalogues of over 700 stars and categorised them based on whether they hosted high-mass planets (greater than 50 Earth masses) or low-mass planets (less than 30 Earths). For these stars, as well as a sample not known to have any planets, they calculated their age and birth location within the Galaxy. They then looked for correlations between the kinds of planets they hosted and when and where the star had formed.

Overall, they found planet-bearing stars have a higher metallicity, are younger and formed closer to the Galactic centre compared to those without known planets. These relationships are especially strong for the high-mass planets they studied. They also showed that the likelihood of a star having any planets at all decreases the further out into the Galactic disc you go.

> ***"They showed that the likelihood of a star having any planets at all decreases the further out into the Galactic disc you go"***

Teixeira's analysis is an important confirmation of our understanding of the chemical evolution of the Galaxy. But a fun interpretation of their study is that it also tells you the most interesting parts of the Galaxy to visit as a Federation starship captain. If your science officer wants to study lots of gas giant planets, you're best off trekking towards the centre of the Galaxy. But smaller, rocky planets can still be found much further out in the Galactic disc.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading… *Where in the Milky Way do Exoplanets Preferentially Form?* by Joana Teixeira et al.
Read it online at: arxiv.org/abs/2501.11660

NASA/JPL-CALTECH, PETER PREDEHL/MPE/IKI

Puzzle of the Milky Way's 'superbubbles'

The Galaxy's black hole may belch out giant bubbles after gobbling up stars

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Fifteen years ago, astronomers looking through data from the Fermi Gamma-ray Space Telescope noticed odd bubbles that extended above and below the Milky Way's disc. Stretching tens of thousands of lightyears across and apparently centred on the Galactic centre, these features were recently joined by larger 'superbubbles', spotted in the data obtained by the eROSITA X-ray satellite.

But what are they? The fact that they seem to be aligned with the Galactic centre suggests the supermassive black hole that lurks there – or the activity that happens when material accretes onto it – might be responsible. But there isn't enough energy being pumped into the Galaxy today from this source to get anywhere close to what's needed.

Any explanation needs to account for both energetic gamma-ray bubbles and the larger X-ray features. Most attempts at an explanation assume that, in the recent past, the black hole at the centre of the Galaxy was growing rapidly. If so, the Milky Way would have resembled nearby galaxies which have active galactic nuclei surrounded by a hot accretion disc and powering jets of rapidly moving material stretching out into the Galaxy.

> **"Could the Milky Way really have gone from being in such an active state to today's somnolence in a few million years?"**

Enormous burst of energy

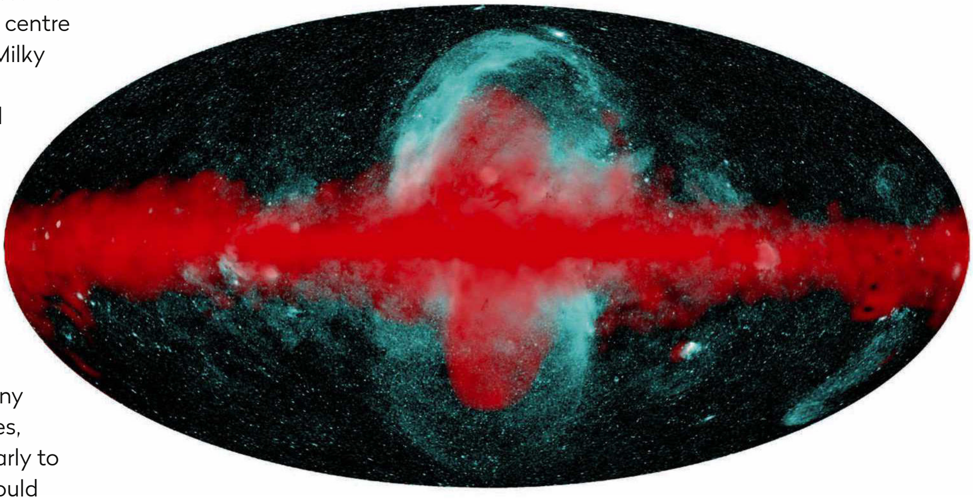
But could the Milky Way really have gone from being in such an active state to today's somnolence in at most a few million years? This is controversial, but to many it seems unlikely. Worse, to match the bubbles, these jets – presumably ejected perpendicularly to the accretion disc around the black hole – would have to been aligned with the Galactic poles. But observations with the Event Horizon Telescope, which provided images of the disc that exists around the black hole today, show the disc is tilted.

This month's paper, therefore, provides simulations to support another hypothesis. The authors still blame the black hole, but consider what happens when it consumes a star, a phenomenon occasionally spotted elsewhere and known as a Tidal Disruption Event, or TDE. In a galaxy the mass and shape of the Milky Way, an unlucky star should wander past the central black hole roughly once every 10,000–100,000 years, producing a burst of light and radiation as it is ripped apart, but leaving little long-term trace.

Each of these events produces an enormous burst of energy, which the researchers inject into a simulation of the Milky Way, capable of tracing the behaviour of our Galaxy's gas and particles.

The result is surprisingly convincing replicas of the Milky Way's bubbles, with shocks spreading outwards from the galactic centre gathering up and exciting material on their way. Repeated TDEs make the bubbles long-lived features, renewed by successive episodes of snacking on stars.

So is the mystery solved? The details aren't quite right, and the shape of the gamma-ray bright bubbles produced by the simulation doesn't really match what Fermi sees. The authors argue that there are many variables – from the frequency and brightness of each TDE through to the structure of the Galaxy itself that the model starts with – that could be tweaked. That seems like a reasonable argument to me, and I'd bet that what we've been staring at for the last 15 years is leftovers from a black hole's habit of snacking on stars.

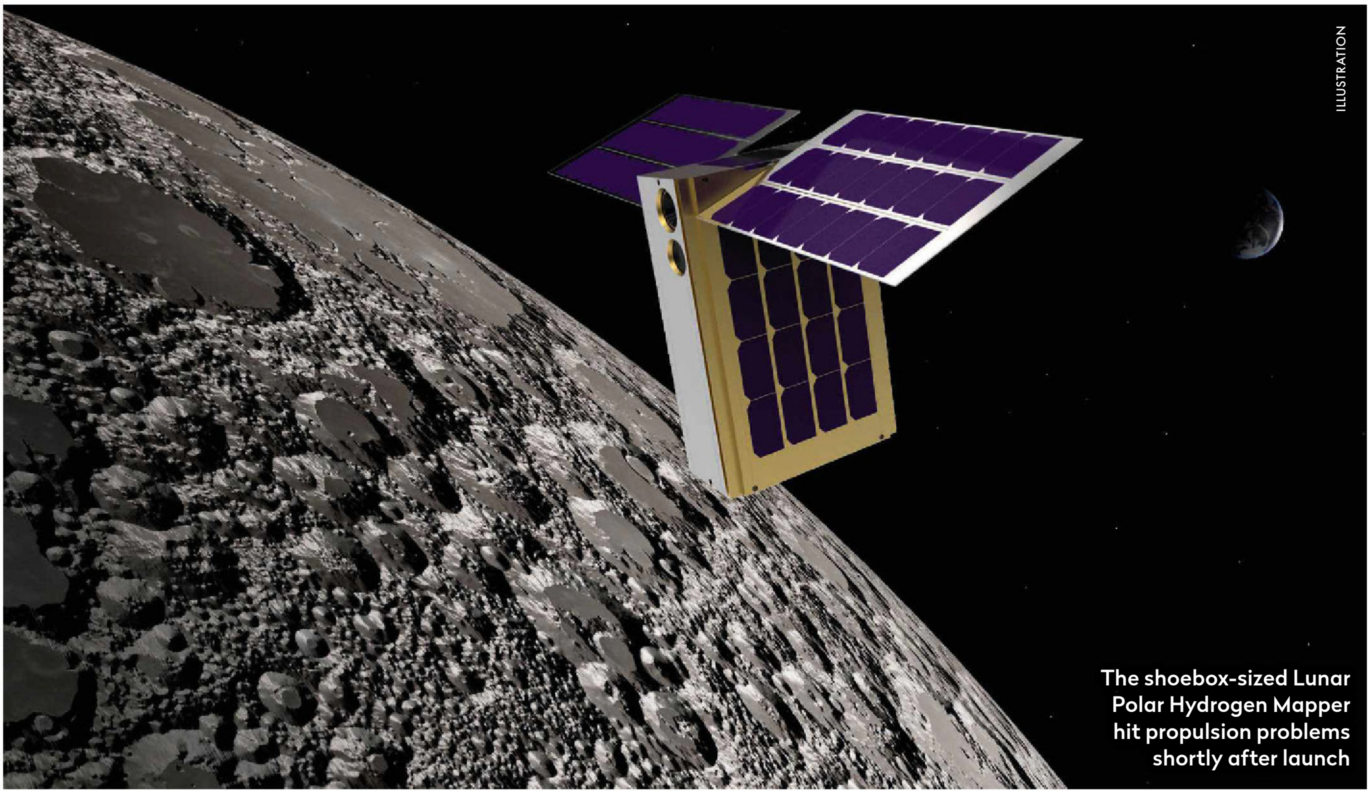


▲ **Comparison of the morphology of the two bubbles in our Galaxy: eROSITA's X-ray superbubbles in blue and the Fermi gamma-ray bubbles in red**

Chris Lintott was reading… *Tidal Disruption Events as the Origin of the eROSITA and Fermi Bubbles* by Tassilo Scheffler et al.
Read it online at: arxiv.org/abs/2501.18713

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



The shoebox-sized Lunar Polar Hydrogen Mapper hit propulsion problems shortly after launch

In 2022, **Craig Hardgrove** told *The Sky at Night* about his Moon-ice-mapping project which would piggyback on NASA's Artemis I. Here he looks back at how things went

Back in 2022, I spoke to the *Sky at Night* TV show and this magazine about the impending launch of a mission I'd spent the last seven years working on. At the time, we were on the cusp of sending a small but ambitious spacecraft to the Moon – one that aimed to push the boundaries of what CubeSats could achieve in deep space.

The Lunar Polar Hydrogen Mapper, or LunaH-Map, was designed to map water and ice hidden within permanently shadowed regions near the lunar poles. Launched on 16 November 2022 as a secondary payload aboard Artemis I, it aimed to demonstrate how small spacecraft could conduct high-value planetary science. A CubeSat about the size of a shoebox, LunaH-Map carried a miniature neutron spectrometer and an iodine-based electric propulsion system. With a budget under two per cent of a typical NASA planetary mission, it sought to prove that small, low-cost satellites could deliver valuable science.

The launch itself was exhilarating, but the real test came afterwards – confirming the spacecraft was healthy and operating correctly. Relief soon turned to excitement as we received the first science data. However, this was soon tempered by disappointment when the novel iodine-based thruster failed to ignite, likely due to a stuck valve caused by prolonged storage and limited hands-on access before launch. Without the necessary thrust to enter orbit, LunaH-Map could not reach its intended science phase.

The team raced to fix the issue before the brief window for a proper trajectory closed. Despite our efforts, the thruster remained stuck and we ultimately had to say goodbye to the original plan. During its fly-by, LunaH-Map collected several hours of data. This preliminary data confirmed the spacecraft was sensitive to the flow of neutrons, which, in a fully operational mission, would have been used to infer the presence of hydrogen. Though limited in scope, these measurements demonstrated that a miniaturised neutron spectrometer could successfully operate in deep space and respond to varying radiation environments.

The LunaH-Map mission also enabled the development of a dedicated mission operations centre, forged commercial partnerships and provided

MASTER/GETTY, SETI INSTITUTE, MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY

hands-on experience for undergraduate and graduate students, shaping the next generation of engineers and scientists. Notably, the mission's achievements paved the way for the upcoming Lunar-VISE (Vulkan Imaging and Spectroscopy Explorer) endeavour. Its gamma-ray and neutron spectrometer instrument will draw upon LunaH-Map's breakthroughs, using enhanced gamma-ray sensitivity to map thorium enrichments and investigate subsurface hydrogen deposits.

LunaH-Map highlighted the challenges of flying as a secondary payload on a large rocket. Long delays between spacecraft delivery and launch contributed to the propulsion problem. Despite this setback, we proved that autonomous deep-space operations for small satellites are feasible.

Ultimately, LunaH-Map was about pushing boundaries. With just a fraction of a traditional planetary science mission budget, it successfully operated en route to the Moon, collected science data and demonstrated the potential of small spacecraft for planetary exploration. The mission's legacy will guide and inspire the next generation of CubeSats, reminding us that every space endeavour is a testament to our curiosity, ingenuity and determination.

Craig Hardgrove is an assistant professor at Arizona State University and the principal investigator of the LunaH-Map mission

Looking back: The Sky at Night

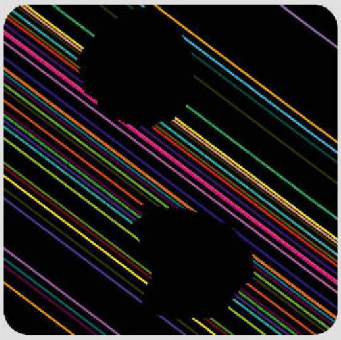
5 April 1978

The 5 April 1978 episode of *The Sky at Night* took a look at the many asteroids scattered around our Solar System. Millions of the rocks are located in the asteroid belt between Jupiter and Mars, yet they remained hidden until astronomer Giuseppe Piazzi discovered the first asteroid, Ceres, in 1801.

The problem is that the rocks are too far away and too small to be seen with the naked eye. Even with a telescope, they are little more than dots of light in the sky. At the time the episode was broadcast, our only close-up view had come courtesy of Pioneer 10, which passed by 307 Nike in 1972.

However, Patrick was joined on the show by Gordon Taylor, an astronomer from the Royal Observatory Greenwich who had developed a unique way to obtain more information about asteroids using Earth-based telescopes. Taylor was an expert in occultations, where one cosmic object passes in front of another, temporarily blocking out its light. By the 1970s, asteroid orbits were known with enough accuracy that Taylor could predict when one of the space rocks would occult a distant star. Since bigger asteroids take longer to pass across a star, astronomers can estimate the size of the asteroid by measuring how long it makes the star blink out of the sky.

Today, amateur astronomers across the world watch such occultations. As each person has a slightly different view of the asteroid, their observations combine to create surprisingly detailed maps of our distant rocky neighbours.



▲ Asteroid sizes and shapes can be gleaned from their shadows

The Sky at Night

APRIL

Asteroid Strike

Early this year, the world experienced a moment of panic as asteroid 2024 YR4 was found on a potential collision course with Earth. *The Sky at Night* team take a look at how astronomers' observations took the asteroid from having the highest impact risk ever recorded to a mere close call, and what might have happened if it had been heading for a strike on our planet.

BBC Four, **14 April**, 10pm
(first repeat will be on BBC Four, date and time to be confirmed)
Check www.bbc.co.uk/skyatnight for more up-to-date information

ILLUSTRATION

▲ ***The Sky at Night*** **team explore what we've learned from February's asteroid scare**

Perpetual lunacy

The extraordinary new **C1 Moonphase** from Christopher Ward. A watch that tracks the moon for 128 years – without missing a beat. With an aventurine glass dial infused with copper oxide to represent the night sky. And a 3D 'moon' sculpted from Globolight© – a luminous ceramic – that precisely follows the real moon's journey across the sky. A watch this advanced can cost up to £45,000. But the C1 Moonphase starts from less than £2,000. As someone once said, you don't have to be mad to work here...

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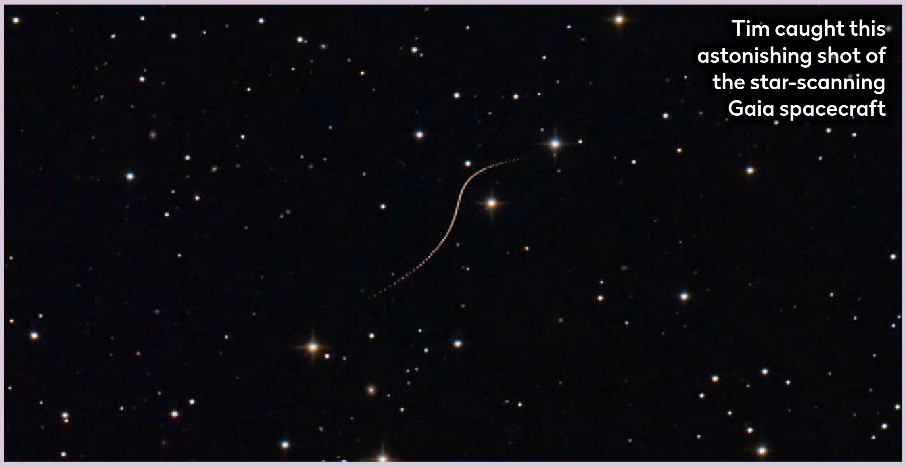
MESSAGE OF THE MONTH

Rare glimpse of the supreme stargazer



Tim caught this astonishing shot of the star-scanning Gaia spacecraft

During January and February, the Gaia spacecraft went through a series of end-of-mission engineering tests that put it into an orientation that reflected more sunlight towards Earth and made it a better imaging target.

Here's the image of it I managed to take from my garden in suburban Surrey. It shows the track of the spacecraft relative to the stars during almost a complete passage across the sky, from 8:30pm on 4 February to 5:30am the next day. During the run, a total of 250 frames were shot at around two-minute intervals and I used 84 of these for the Gaia track.

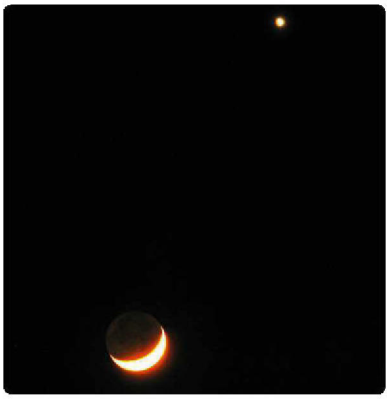
Gaia is at the L2 Lagrange Point, about 1.5 million kilometres away from Earth in the direction opposite to the Sun. The sinuous shape of its track in the image and the changing apparent speed of movement (seen in the variation in spacing between the dots) are both almost entirely a result of a parallax effect caused by the rotation of Earth during the night. This seems fitting, given that Gaia's data allowed distances to the stars to be calculated using parallax measurements. Thanks for the ever-interesting magazine. I look forward to it dropping through my letterbox each month.

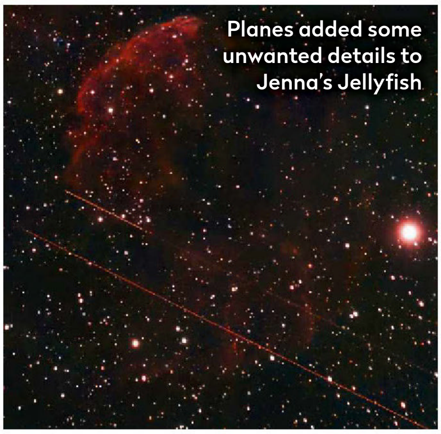
Tim Ellison, via email

This is a remarkable image, Tim. Congratulations on both the capture and the processing! – ***Ed.***

Tweet

Andy Jacklin
@AndrewJacklin • 1 February
The #crescent #Moon and #planet #Venus shining bright this evening. Captured from Trimley St Mary #Suffolk @skyatnightmag





Planes added some unwanted details to Jenna's Jellyfish

Jelly photobomb

I bought a Seestar S30 as I wanted to expand my photography to include the night sky, which has always fascinated me. I used it for the first time last week from my back garden and took this picture of the Jellyfish Nebula, taking 10-second exposures over 30 minutes. But when I looked at the image, I noticed two lines. I'm not sure what they are. There was nothing obstructing the telescope. Could they be plane trails or Starlink satellites?

Jenna Jackson, Scarborough, UK

That's a great image of the Jellyfish Nebula, Jenna. The interlopers you've caught in the frame are aeroplanes. Their flashing navigation lights appear as lines of dots in long-exposure images. – ***Ed.***

Catch some rays

I always check your Sky Guide and listen to your Star Diary podcast. It's good to know all these clair-obscur effects on the Moon. I sometimes share them in my own (Dutch) astronomy podcast (Podcast Maan en Planeten). I have a suggestion for a clair-obscur effect you might feature. ▶

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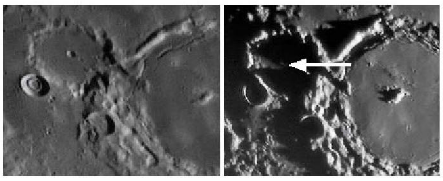

▲ Hesiodus (left) and the ray seen when light passes through a gap in the crater wall

▶ It's called the Ray of Hesiodus. Between the crater Hesiodus and Pitatus, there's a gap in the crater wall and when the Sun rises, a ray of light can fall through it onto the surface of Hesiodus.
Marcel-Jan Krijgsman, the Netherlands

Belt origin story

This question has likely been explored before, but do we know the total mass of the objects in the asteroid belt, and could there have once been a planet occupying the large gap between the orbits of Mars and Jupiter? Is it possible that this planet suffered some type of catastrophe that caused it to be broken up into asteroid-sized pieces which now occupy that orbit? I really enjoy your magazine.
Dr Amjad Junaid, Hamilton, Ontario, Canada

Instagram

kon_astro • 16 February
Mars under excellent seeing. A moment of very good transparency and seeing resulted in my best Mars with the 12-inch. #mars @bbcskyatnightmag

That's a good questions, Amjad. The total mass of all the asteroids in the belt is estimated to be just three per cent of the Moon's mass. Most astronomers think that they never formed a single planet, since Jupiter's gravity kept them from coming together. **– *Ed.***

CORRECTION

Just after we went to press, we learned that, at 62 hours and 6 minutes, Suni Williams had broken Peggy Whitson's previous record for the greatest amount of time spent spacewalking by any woman ('Beyond the airlock: 60 years of spacewalks', March issue).

SOCIETY IN FOCUS

An RASC event in Irving Nature Park during 2017's solar eclipse

MIKE POWELL

The **New Brunswick Centre of the Royal Astronomical Society of Canada** (RASC NB) began in 2000 with approximately 30 members. The current membership is around 65–75, with a high of 110 a decade ago. We have nine meetings annually, which used to be shared among the three largest population centres in our New Brunswick province of 850,000 people, until the pandemic necessitated online meetings. Although we have no infrastructure, we have a Coronado PST, Herschel wedge and other items for members' usage.

Astronomy outreach has been the focus of RASC NB since its inception and particularly since the International Year of Astronomy in 2009. Four weekend and several single-night star parties are held annually at provincial, national and local parks, featuring public talks, solar observing and evening observing. Between 2009 and 2011, RASC Dark-Sky Preserve status was awarded to three parks, and Urban Star Park status to another. Centre members have been active in giving presentations and staging observing events for many schools, youth and other groups. For the past five years, some members have presented the Sunday Night Astronomy Show via 'Astronomy by the Bay' on Facebook and YouTube, drawing viewers worldwide. Between 2012 and 2024, we recorded 2,135 outreach events, reaching 100,000 people and another 400,000 online.

Curt Nason, RASC NB president and outreach coordinator
▶ **www.rascnb.ca**

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This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And surviving a stroke is just the start of a long and gruelling recovery journey. If you or someone you love has been affected by stroke – you'll know just what that means.

You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries, and stroke survivors and their families have the support to find the strength and determination they need to find their way back to life.

Your promise today gives strength for tomorrow. Please, leave a gift in your Will to the Stroke Association.

Find out how by calling 020 7566 1505
or email legacy@stroke.org.uk
or visit stroke.org.uk/legacy

Finding **strength** through **support**

Stroke Association

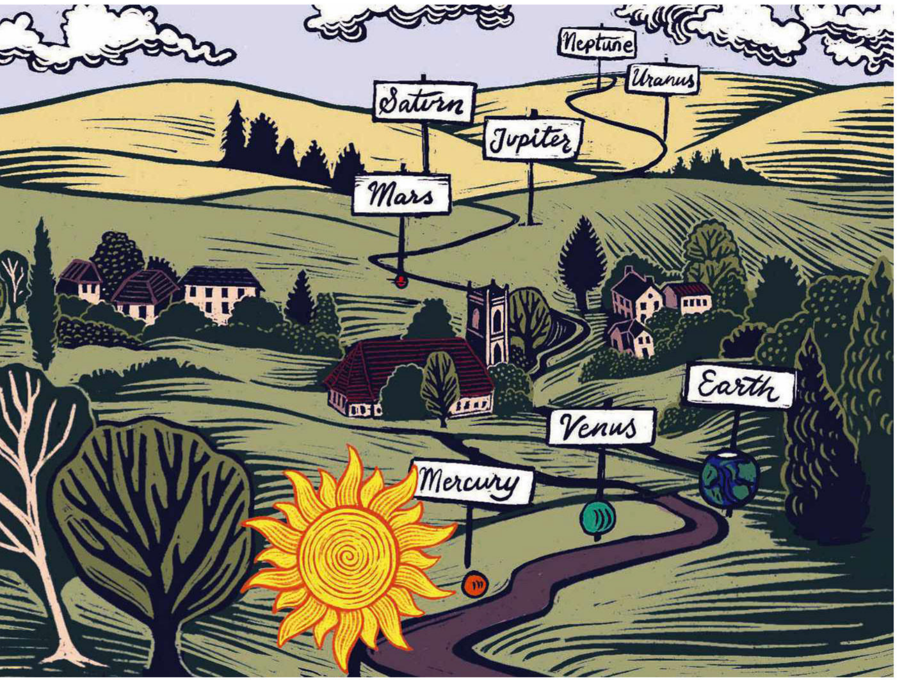
The Stroke Association is registered as a charity in England and Wales (No 211015) and in Scotland (SC037789). Also registered in the Isle of Man (No. 945) and Jersey (NPO 369), and operating as a charity in Northern Ireland.

The astronomer's forum

FIELD OF VIEW

Walking the Solar System

There's a great way to gain a better understanding of the sheer scale of the Solar System, says **Paul Fisher Cockburn** – on foot



Paul Fisher Cockburn is a science and astronomy writer

Most scientists agree that nothing and no one can travel faster than the speed of light – with the possible exception (at least according to the late Douglas Adams) of bad news. However, the good news is that there's one way in which we can all break the light barrier, metaphorically – and you don't even need a spaceship.

Last October, the Dirleton Solar Walk officially opened in East Lothian, near Edinburgh, Scotland. This 1:3.6 billion scale model of the Solar System, which stretches just over 1.2km (0.7 miles), means that every step you take represents millions of kilometres in space. To complete the route in either direction, even at a slow pace, means that – symbolically, at least – you're necessarily breaking the laws of physics.

Currently there are around half a dozen outdoor models of the Solar System across the UK. Arguably the oldest is the Somerset Space Walk, which uses the towpath of the 22km (14-mile) Bridgwater and Taunton Canal to display a model of the Sun and its planets in their proportionally correct sizes and distances apart. Back in 1997, Pip Youngman, described as a "Tauntonian inventor, poet, astronomer and general dreamer of interesting things", was inspired to create the Walk by his frustration at the inability of books and pictures to accurately represent just how big the Solar System really is.

After all, search online for images of the Solar System and you will most likely see the planets all lined up close together; perhaps to scale in terms of their sizes, but certainly not when it comes to the vast distances between them.

So the Somerset Space Walk's model of the Sun is the size of a small car, placed at the centre-point of the canal; its representations of Pluto (at the time classified as a planet) are the size of a pea, located 11km (10.6 miles) away in both directions to show the extent of its orbit.

As examples of public education, most Solar System walks established in the UK are easily accessible on existing public routes. The Dirleton Solar Walk is on a stretch of the John Muir Way, the walking and cycling route which crosses central Scotland between Helensburgh and the Scottish conservationist's birthplace, Dunbar. The Cycle the Solar System artwork commissioned by the charity Sustrans is on part of National Cycle Network Route 65 between York and Selby, while the nearby York Solar System Model (instigated by the University of York's astronomy society) provides a slightly shorter but similar experience through the heart of the university campus.

Not all such models are permanent, however: Our Place In Space was a series of appropriately placed sculptures created by artist Oliver Jeffers, which temporarily landed in Derry/Londonderry, then shifted to Belfast, Cambridge and Liverpool during 2022 and 2023, along with a series of astronomy-themed events and digital learning experiences.

What they all share in common is a desire to better reflect the true scale of the Solar System – and especially all that empty space you really want to speed through as quickly as possible, whatever Einstein says.

JOANNA LISOWIEC/FOLIO

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News

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Conquering the Realm of the Galaxies

The constellation of Virgo is littered with glowing galaxies. Join **Rod Mollise** on a tour through some of its best sights

One spring afternoon, many years ago, I was idly thumbing through an astronomy book from the library when I came upon a spring star chart with a portion of the sky labelled 'The Realm of the Galaxies'. That sounded so intriguing, I began reading in earnest.

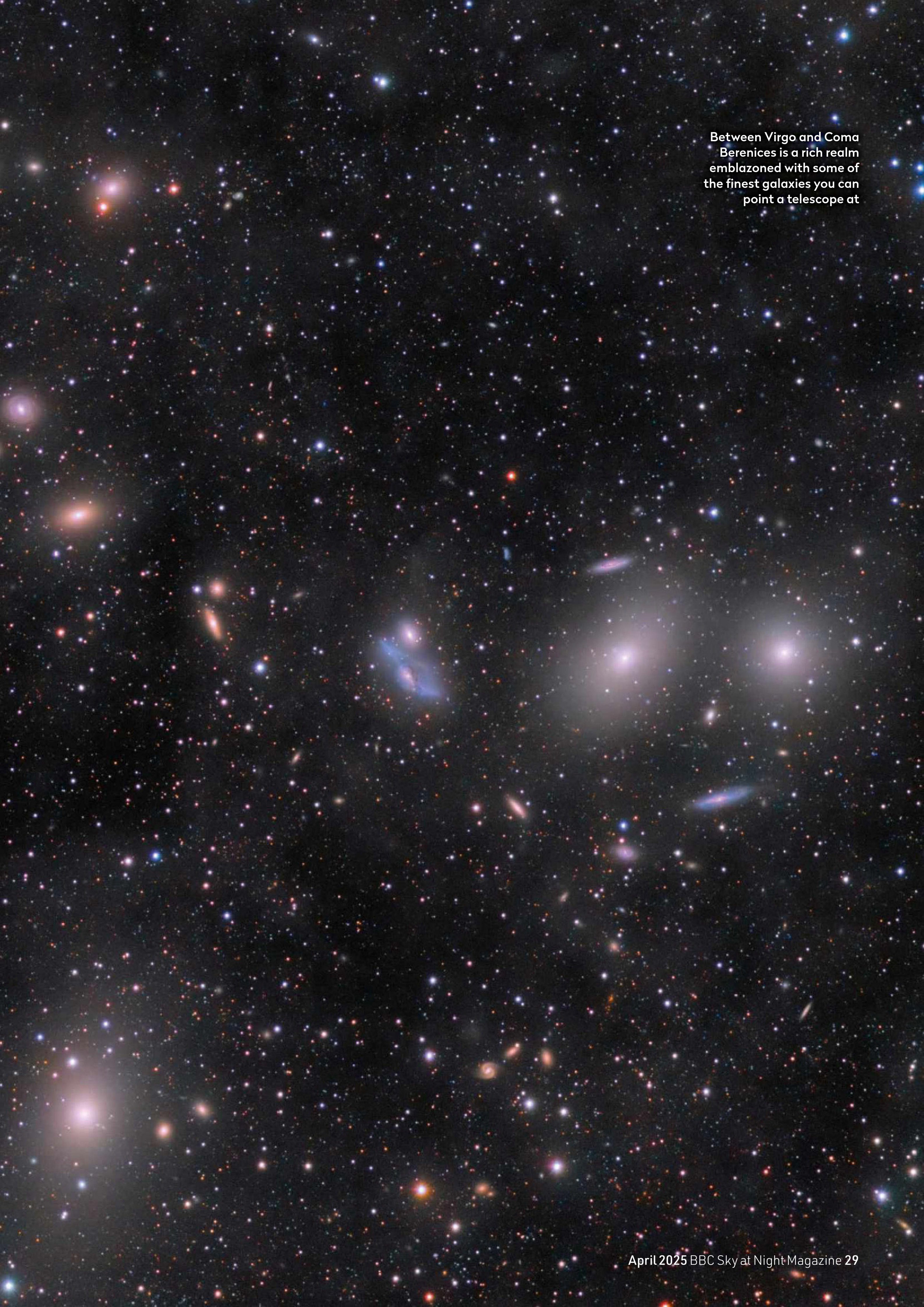
I learned this 'realm' is a great cluster of galaxies called the Virgo–Coma Cluster, island universes just like our Milky Way. It stretches across the spring sky from northernmost Coma Berenices to southernmost Virgo and is home to some 2,000 galaxies. While the Milky Way is a member of this Virgo–Coma Cluster, the heart of this great agglomeration of galaxies is a mind-bending 54 million lightyears distant. By the time I finished reading, I wanted to see the Realm for myself.

My journey through the Realm of the Galaxies wasn't easy in the beginning. All I had was a 3-inch telescope and a suburban backyard. Observing Coma–Virgo can be difficult because of the nature of galaxies, the most distant deep-sky objects to observe. Don't let that discourage you, though; all the galaxies we'll visit tonight are visible from light-polluted skies with modest telescopes.

It's a beautiful, mild spring evening. Virgo is well over the horizon, the Moon doesn't rise until late and our wonderful telescope awaits us outside. We begin in the north, in the little constellation of Coma Berenices with one of the most spectacular galaxies of the Northern Hemisphere.

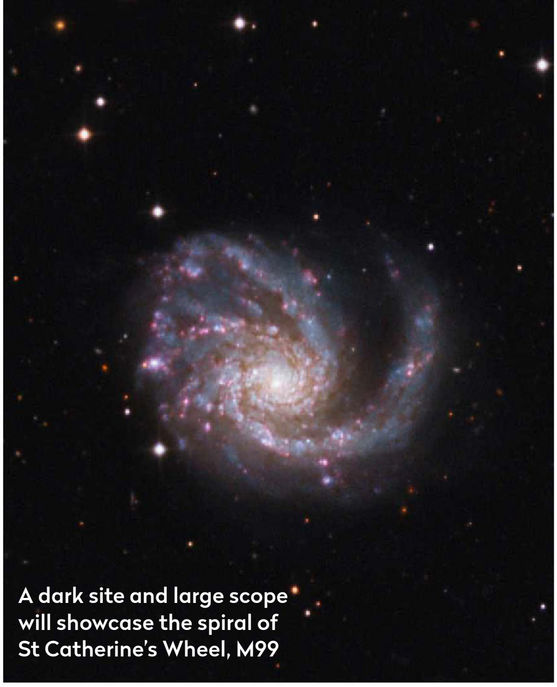
Let's hit the trail...

Messier 64, The Black Eye Galaxy, is relatively bright at magnitude +8.5 and not overly large ▶



Between Virgo and Coma Berenices is a rich realm emblazoned with some of the finest galaxies you can point a telescope at

Step up the aperture to see the dark dust lane in the stunning Black Eye Galaxy



A dark site and large scope will showcase the spiral of St Catherine's Wheel, M99

▶ at 10.7 x 5.1 arcminutes across, so its light is well-concentrated, making it appear brighter in the eyepiece. A 4-inch telescope will show an attractive oval of nebulosity with a bright, almost starlike centre. Seeing the feature that gives this galaxy its name – a huge band of dark dust near its centre – normally requires an 8-inch scope from suburban skies.

A little over 11° south-southwest, near the Coma Berenices border with Virgo, is **M99**, St Catherine's Wheel. In long-exposure images, the far-flung arms of this spiral make it look like a cosmic firework. Unfortunately, this galaxy's face-on orientation to us means its magnitude +9.90 light is spread out over a wide area, so it will look dimmer to your eye. From the suburbs, a 4- to 10-inch instrument shows a slightly elongated nebulous ball 5.5 x 4.7 arcminutes in size, surrounding a brighter centre. From a dark site, a 10-inch telescope will begin to show hints of spiral structure in the haze surrounding the galaxy's core.

Moving just 2.3° southeast takes us over the border into Virgo to elliptical galaxies **M84** and **M86**. M84 is bright at magnitude +9.1 and only 6.5 x 5.6 arcminutes in size. As with most ellipticals, there's not a lot of detail – it's a bright, round ball that looks like a small, unresolved globular star cluster. It wouldn't be of much interest if it weren't for another elliptical galaxy, M86, in the same field only 16 arcseconds away. M86 is a little brighter than M84 at magnitude +8.9 and obviously elongated at 8.9 x 5.8 arcminutes across.

The two bright galaxies paired together make for a very attractive view, but things are about to get even more interesting. M84 and M86 are at one end of

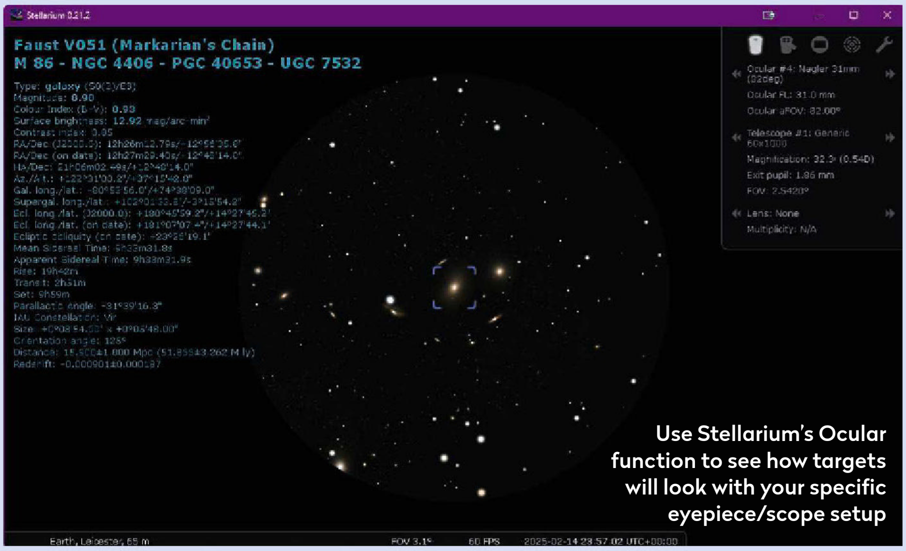
Finding your way

The Realm is jam-packed with galaxies, so how can you be sure you're looking at the right one?

Today, many amateur astronomers use computerised Go-To telescopes that find objects automatically. That's good for suburban observers when it comes to the Realm of the Galaxies, where few stars will guide you to targets the old-fashioned way with a finderscope, especially in the galaxy-rich area encompassed by the stars Epsilon and Nu Virginis.

Go-To may make finding galaxies easy, but it doesn't make identifying them simple. Even accurate Go-To telescopes don't always place target objects dead centre. In the heart of the Virgo Cluster, there are often multiple fuzzballs in the eyepiece. Which is the target? One helpful tip is something I used to call 'eyepiece hopping'. An eyepiece-field-sized chart, with each galaxy labelled, makes it easy to identify the quarry; you hop from galaxy to galaxy in the eyepiece field, identifying them as you go. Charts tailored to your telescope and eyepiece are easy to produce with computer software, such as Stellarium's Oculars function.

Of course, to identify the galaxies in that field, you must first be able to see them. Don't be afraid to use higher magnifications – 150x and even higher. Using more magnification will spread out the background light pollution in the field of view and improve contrast.



```
Faust V051 (Markarian's Chain)
M 86 - NGC 4406 - PGC 40653 - UGC 7532
Type: galaxy (S0(3)/E3)
Colour Index (B-V): 0.93
Surface brightness: 12.92 mag/arc-min²
Apparent Sidereal Time: 9h33m31.9s
Rise: 19h42m
Transit: 2h51m
Set: 9h59m
Parallactic angle: -31°39'16.3"
IAU Constellation: Vir
Orientation angle: 125°
```

```
Ocular #4: Nagler 31mm (82deg)
Ocular FL: 31.0 mm
Ocular aFOV: 82.00°
Telescope #1: Generic 60x1000
Magnification: 32.3x (0.54D)
Exit pupil: 1.86 mm
FOV: 2.5420°
Lens: None
Multiplicity: N/A
```

```
Earth, Leicester, 55 m     FOV 3.1°     60 FPS     2025-02-14 23:57:02 UTC+00:00
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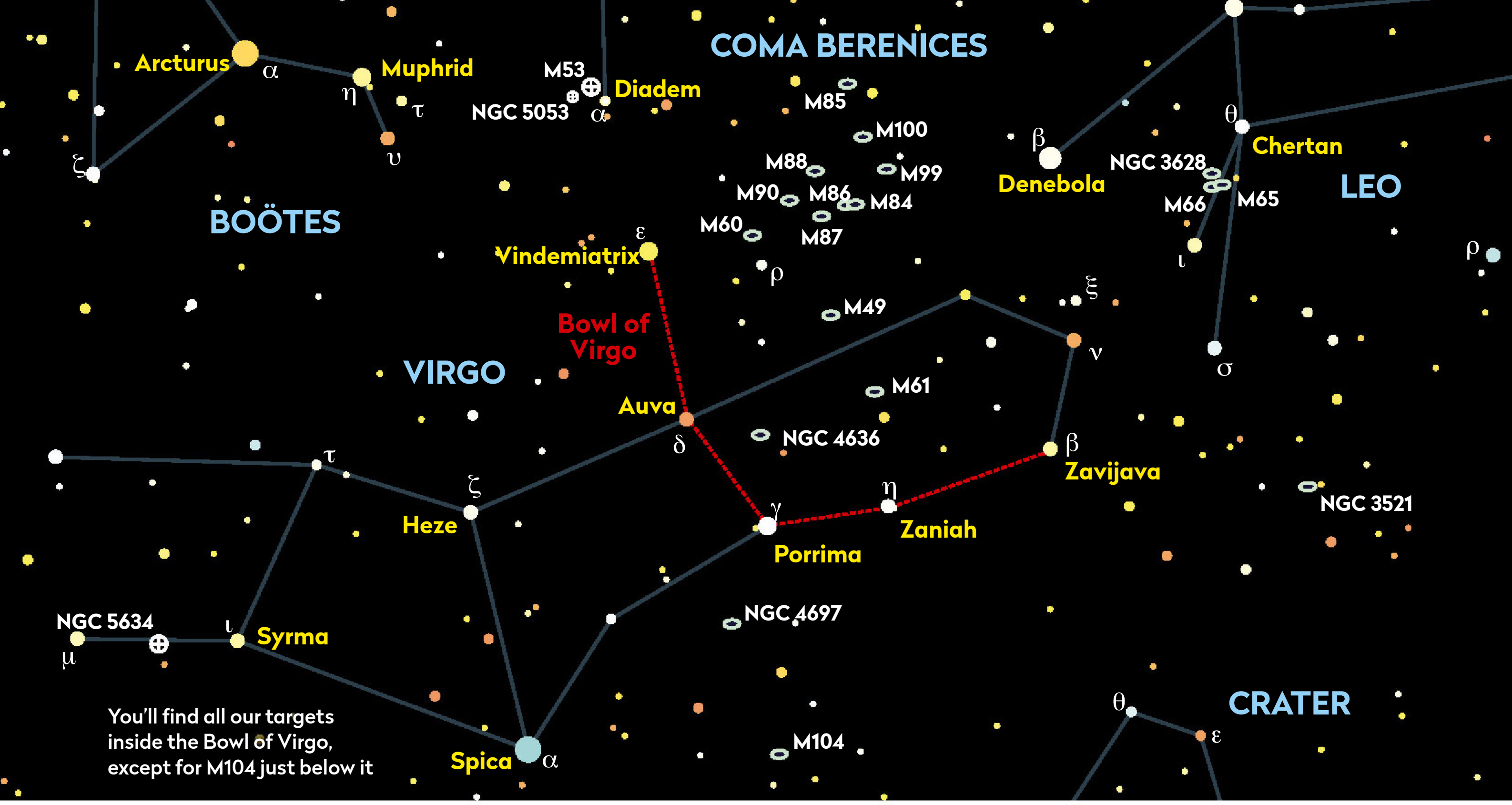
Use Stellarium's Ocular function to see how targets will look with your specific eyepiece/scope setup


COMA BERENICES
Arcturus
α
Muphrid
η
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ζ
M53
NGC 5053
Diadem
α
M85
M100
M88
M99
M90
M86
M84
M60
M87
β
Denebola
θ
Chertan
NGC 3628
M66
M65
LEO
ι
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Vindemiatrix
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M49
ξ
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Bowl of Virgo
VIRGO
Auva
δ
M61
NGC 4636
β
Zavijava
τ
ζ
Heze
γ
Porrima
η
Zaniah
NGC 3521
NGC 4697
NGC 5634
μ
ι
Syrma
θ
CRATER
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Spica
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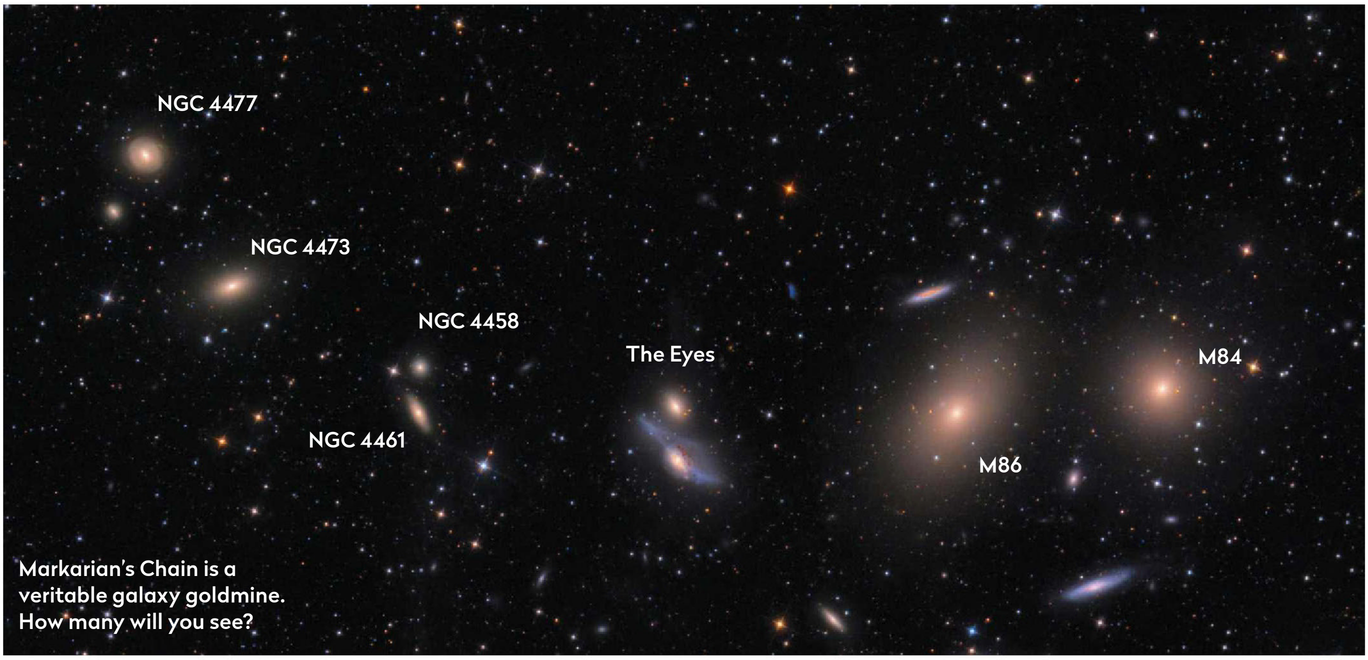
M104

You'll find all our targets inside the Bowl of Virgo, except for M104 just below it


NGC 4477
NGC 4473
NGC 4458
NGC 4461
The Eyes
M84
M86

Markarian's Chain is a veritable galaxy goldmine. How many will you see?

The Eyes have it: lenticular galaxy NGC 4438 and the smaller spiral NGC 4435 are an interacting pair

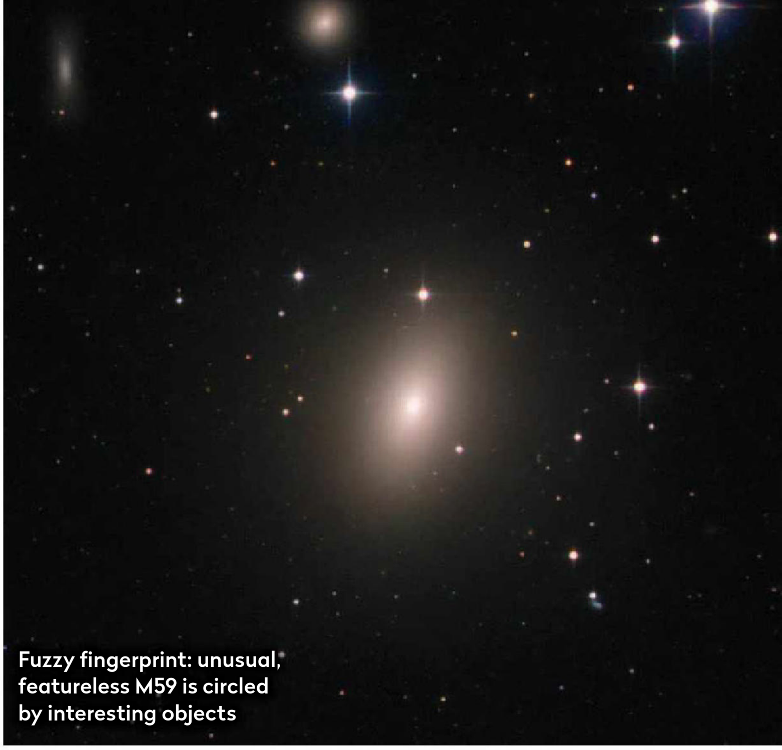
what's known as **Markarian's Chain**, a curving line of galaxies stretching 1.25° to the west across the heart of Virgo. In addition to M84 and M86, the members are NGC 4477, NGC 4473, NGC 4461, NGC 4458, NGC 4438 and NGC 4435. How much of the chain will you see? That depends on your telescope, your skies and your experience. M84 and M86 are the brightest, with the magnitudes of the others ranging down to +12.9.

Look into the Eyes

I particularly recommend you look for the **Eyes Galaxies**, NGC 4435 and NGC 4438. NGC 4438 is a magnitude +10.2, roughly 8.5 x 3.2 arcminutes lenticular galaxy (a type midway between a spiral and an elliptical), while NGC 4435 is a magnitude +10.8 spiral with a size of 3.2 x 2.2 arcminutes. Only 4 arcminutes apart, the two do look like eyes shining in the darkness. ▶

BERNHARD HUBL/CCDGUIDE.COM X 2, MICHAEL BREITE/STEFAN HEUTZ/WOLFGANG RIES/CCDGUIDE.COM, NAWRATIL TOMMY/CCDGUIDE.COM, CHARTS & STELLARIUM SCREENSHOT: PETE LAWRENCE

Supergiant galaxy M87 holds trillions of stars and shoots out a jet of plasma


Fuzzy fingerprint: unusual, featureless M59 is circled by interesting objects

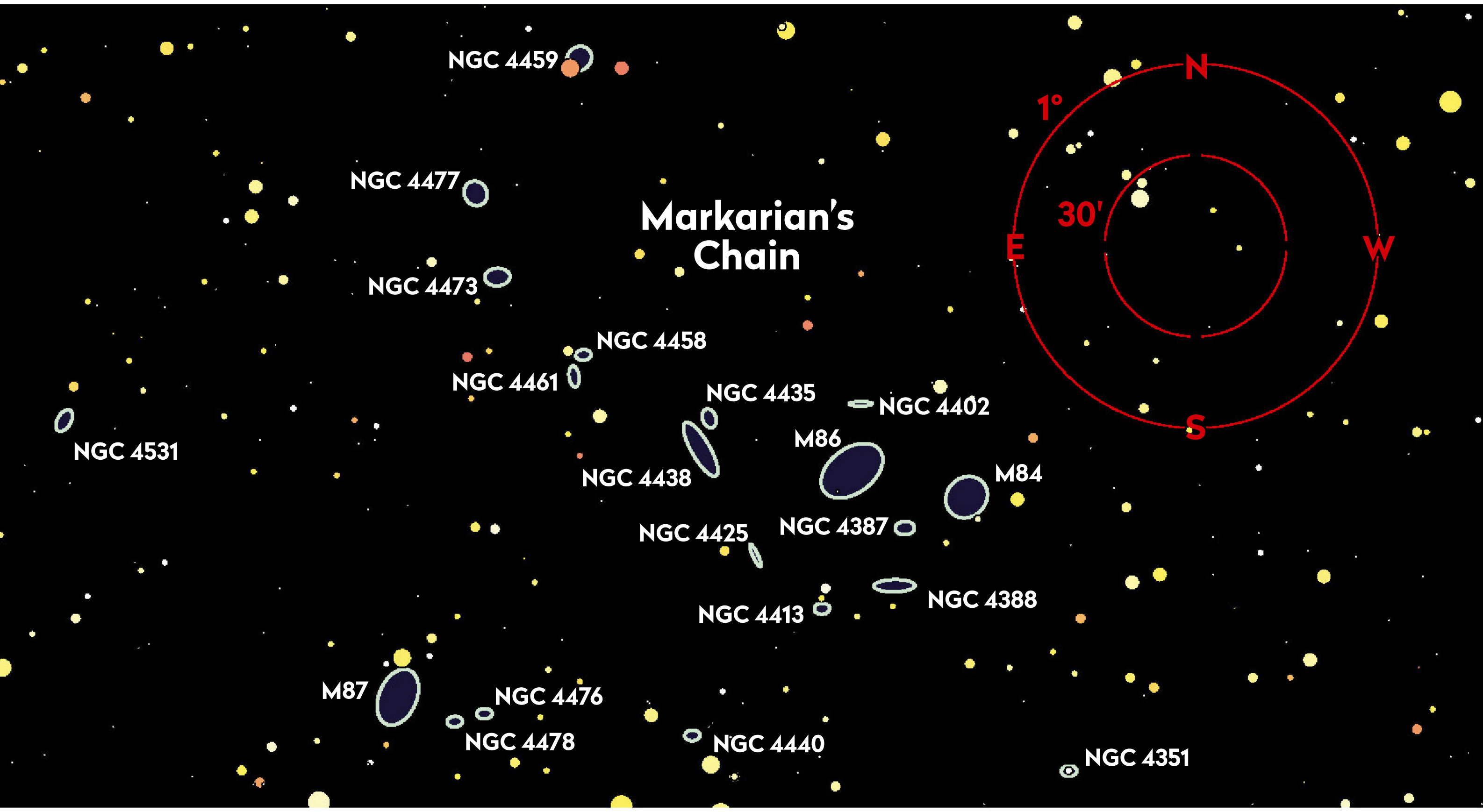
▶ A slew of the telescope just under a degree to the southeast brings us to a galaxy that is both humdrum and amazing: Virgo A, the gigantic **M87**. At magnitude +8.6 and a diameter of 8.3 x 6.6 arcminutes, M87 is difficult to miss in even a small telescope. In my suburban 4-inch reflector, it looks a lot like M13 in Hercules does in the same scope – a bright, round fuzzball. However, M87 is intrinsically interesting given that it is of a size and majesty difficult for the human mind to comprehend. It is the largest and most luminous of the 2,000 galaxies that inhabit Virgo–Coma and has a mass of a trillion Suns.

It's intriguing in an armchair astronomy sort of way, but what is there to see? M87 is also known as Virgo A because it is a radio source. The radio waves are generated by a massive black hole at its heart that is emitting a relativistic jet. Amazingly, so bright is this 5,000-lightyear-long jet, that it can technically be seen in large amateur telescopes… if you happen to have a 25-inch-aperture or larger telescope and excellent dark skies.

Two hazy halos and a hat

A move of 2.8° southeast brings us to the next stop on our tour, Messier 59. **M59** is one of the more interesting galaxies on tonight's journey. While it's yet another Virgo elliptical, it's in an attractive field that contains two bright stars – and multiple galaxies.

▼ Start with its easiest members, M84 and M86, before trying for the rest of Markarian's Chain


NGC 4459
NGC 4477
Markarian's Chain
NGC 4473
NGC 4458
NGC 4461
NGC 4531
NGC 4435
NGC 4402
M86
NGC 4438
M84
NGC 4425
NGC 4387
NGC 4388
NGC 4413
M87
NGC 4476
NGC 4478
NGC 4440
NGC 4351
1°
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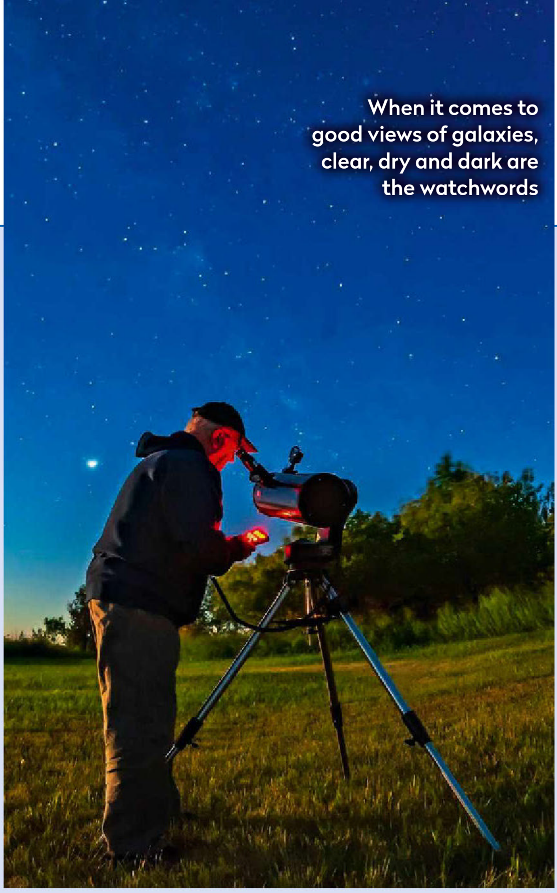


When it comes to good views of galaxies, clear, dry and dark are the watchwords

Tips for galaxy hunters

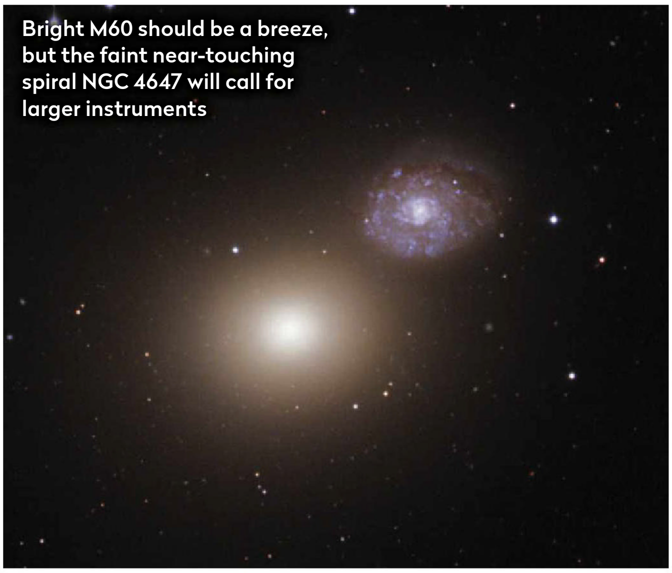
Dark, dry skies are the key to finding even more galaxies

Whether your telescope is large or small, get to the darkest site available to you. There is nothing that's more spoiled by light pollution than galaxies. If you're a new observer, you may be amazed to find a 6-inch telescope under dark skies delivers more galaxies, and details in those galaxies, than a 10-inch under suburban skies. You *can* see many galaxies even from city skies, but darker is always better.

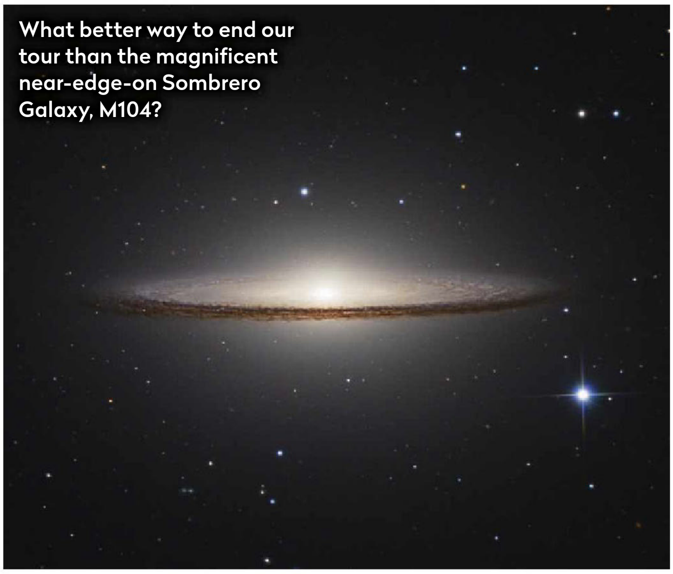
When pursuing the most difficult targets, wait for a dry night. Humidity in the air scatters light pollution and makes it worse. Even on a dry night, you will have to deal with some light pollution. There's nothing you can do about thousands of distant lights, but you can do something about nearby ones. If your eyes can gain a modicum of dark adaptation, you will see more.

Can't convince your neighbours to turn off their floodlights for a few hours? Rig some kind of light shield, something that will protect your eyes from ambient light. That can be as simple as a piece of dark cloth draped over your head while you are at the eyepiece.

Still having trouble seeing an elusive galaxy? Try an old observer's trick: averted vision. Your eyes have receptors for both bright and dim light. To bring the dim light sensors into play, look away from an object, off to the side, not directly at it.



Bright M60 should be a breeze, but the faint near-touching spiral NGC 4647 will call for larger instruments



What better way to end our tour than the magnificent near-edge-on Sombrero Galaxy, M104?

Rod Mollise is an amateur astronomer and writer who lives near Mobile, Alabama. He's the author of *Choosing and Using a New CAT*

Magnitude +9.6 and 5.4 x 3.7 arcminutes in diameter, M59 is a strongly elongated smudge that looks like a fingerprint on black velvet.

Lying 25 arcminutes to the east in the same field is elliptical **Messier 60.** At magnitude +8.8 and a size of 7.4 x 6 arcminutes, it's noticeably rounder than M59. Keep looking on a good night and you'll see yet another galaxy pop into view: magnitude +12.5 spiral **NGC 4647**, which has a size of 2.9 x 2.3 arcminutes. While difficult at times in smaller scopes, I've never failed to see it with my 10-inch Newtonian reflector.

Our last hop of the evening is a large one. Head 23.2° south to what is the most spectacular galaxy of the evening: **Messier 104**, the Sombrero Galaxy. If there's a problem with M104, it's that it's never far from the horizon at higher northern latitudes, reaching a maximum elevation of 25° from the southern UK. That is made up for by its brightness and interesting appearance. It's a magnitude +8.0, 8.7 x 3.5 arcminutes near-edge-on spiral with a prominent central bulge and equatorial dust lane.

At the eyepiece of a 5-inch telescope, I can see the crown of the 'sombrero', the galaxy's central bulge, hides a tiny stellar nucleus. The dust lane that divides the disc, the hat brim, is not easy but can be held steady at 150x magnification on exceptional nights. On the best evenings, the edges of the dust lane don't look straight – there's a curdled appearance. A beautiful object, this is one of the top five Messier galaxies in the entire sky.

Sombrero admired, I pull away from the eyepiece and am surprised to see the night has grown old. The Virgin is sinking in the west and the stars of summer are glimmering in the east. That's okay. There'll be many other nights to visit this great galaxy forest we have barely begun to explore.

MICHAEL BREITE/STEFAN HEUTZ/WOLFGANG RIES/CCDGUIDE.COMX 3, STOCKTREK IMAGES/INC./ALAMY STOCK PHOTO, JOHANNES SCHEDLER/CCDGUIDE.COM, CHART: PETE LAWRENCE

Space factories

from science fiction to reality

Not too long ago, the space economy was a government endeavour. But, as **Ben Evans** reports, commercial players are rapidly changing what the future looks like for industry in space – with far-reaching consequences

One October day in 1969, Soviet cosmonauts Georgi Shonin and Valeri Kubasov attempted in-space manufacturing for the first time. They closed the hatch to the orbital module of their Soyuz 6 spacecraft, retreated to the descent module and activated a vacuum-welding furnace for a series of autonomous tests. What happened next could have killed them both.

Three months after Neil Armstrong and Buzz Aldrin walked on the Moon, a dispirited yet resurgent Soviet Union realigned its efforts to building Earth-circling space stations. Cosmonauts would no longer simply visit space, but live there. And that meant assembling huge off-world structures, fixing or strengthening components weakened by long-term exposure to the low-gravity, high-vacuum and high-radiation environment in Earth orbit.

Aboard Soyuz 6 was a squat green cylinder the size of a small household refrigerator. Weighing 110lb (50kg), the 'Vulcan' furnace included a low-pressure compressed plasma arc, a consumable electrode and an electron beam. It would weld pieces of aluminium alloy, titanium and stainless steel on a tiny turntable.

The experiment took place six hours before Soyuz 6 landed. After an automated trial run, Kubasov reopened the descent module's hatch for a manual test – and was shocked by what he saw. Vulcan had melted the metal samples... and the turntable... and part of the orbital module's floor... and then started firing its electron beam directly onto the spacecraft's hull.

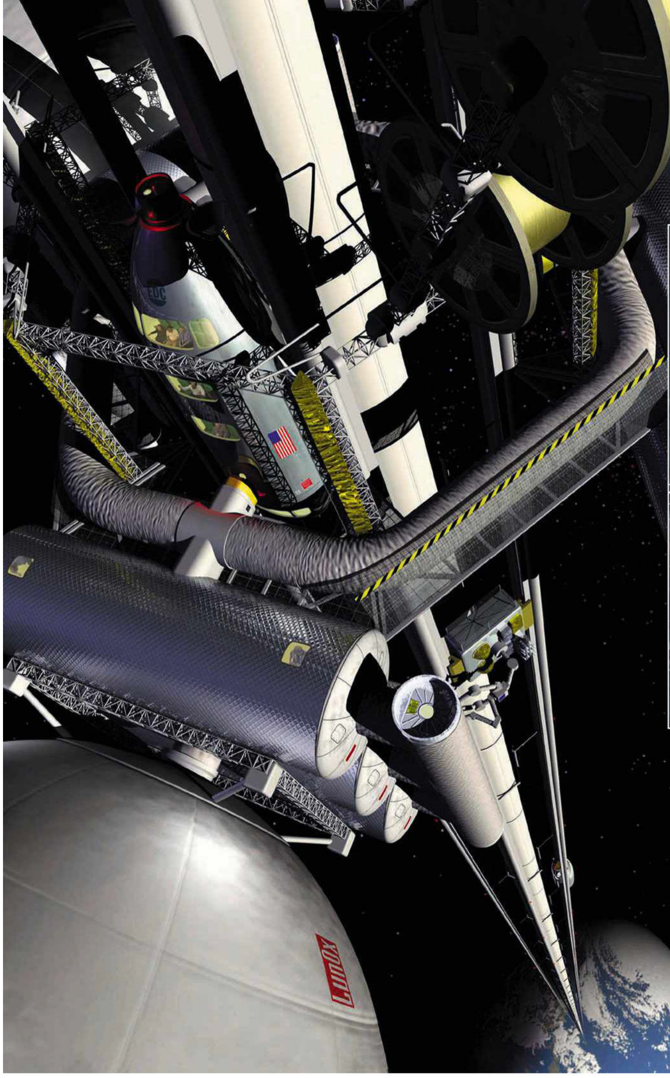
Fearing an imminent decompression, the horrified cosmonauts gathered their samples, shut the hatch and returned to Earth. Not until 1990 and improved détente with the West did the full story emerge. But in the secretive days of the Cold War, the Soviets remained stonily silent, Kubasov noting darkly that Vulcan might prove useful "in emergencies" – ironic words, for Soyuz 6's 'emergency' was caused by the furnace itself.

Manufacturing beyond Earth

Today, the concept of in-space manufacturing (ISM) has expanded to entail fabricating, assembling and integrating tangible goods beyond Earth. It involves transforming raw or recycled materials into components, products or infrastructure by human or robotic manufacturing. There are three ▶

Factories built from space dirt on an asteroid being mined for its multi-trillion-dollar bounty – just one of the visions spurring on a raft of new private space companies

ILLUSTRATION: VICTOR HABBICK VISIONS/SCIENCE PHOTO LIBRARY/ ALAMY STOCK PHOTO



ILLUSTRATION

With the surge in commercial space enterprises, off-world colonies may not be such a distant prospect

▶ types: ISM-for-Earth (goods with improved properties made in space to benefit people on Earth), ISM-for-space (goods made for use in space) and ISM-for-surface (goods produced on the surfaces of other celestial bodies).

Assembling huge space structures has been the stuff of science fiction for decades. Think vast space colonies housing millions of people in near Earth-like conditions; supertall space elevators hoisting cargo out of our planet's strong gravitational well into orbit at a mere fraction of current costs; mining precious minerals from asteroids or gigantic solar array 'farms' gathering sunlight, then beaming down energy via microwaves to satisfy our insatiable power needs.

Manufacturing in space, rather than prefabricating hardware on Earth to assemble it in orbit, allows for greater design flexibility, empowering engineers to think big, unencumbered by the need to squeeze hardware inside narrow rocket payload fairings or meet strict weight limits. But escaping Earth's gravity is notoriously difficult and prohibitively costly – so much so that until recently, ISM advances were impossible to 'scale' commercially.

For decades, ISM occurred solely at the research level. Microgravity allows the production of high-quality semiconductors, pharmaceuticals and super-strong alloys with fewer of the terrestrial defects induced by gravity-driven buoyancy, convection and sedimentation. Materials can be melted, mixed and resolidified for a raft of Earthly benefits, including high-efficiency solar cells, superfast computer chips, microwave circuits, artificial human retinas, infrared sensors and improved medications.

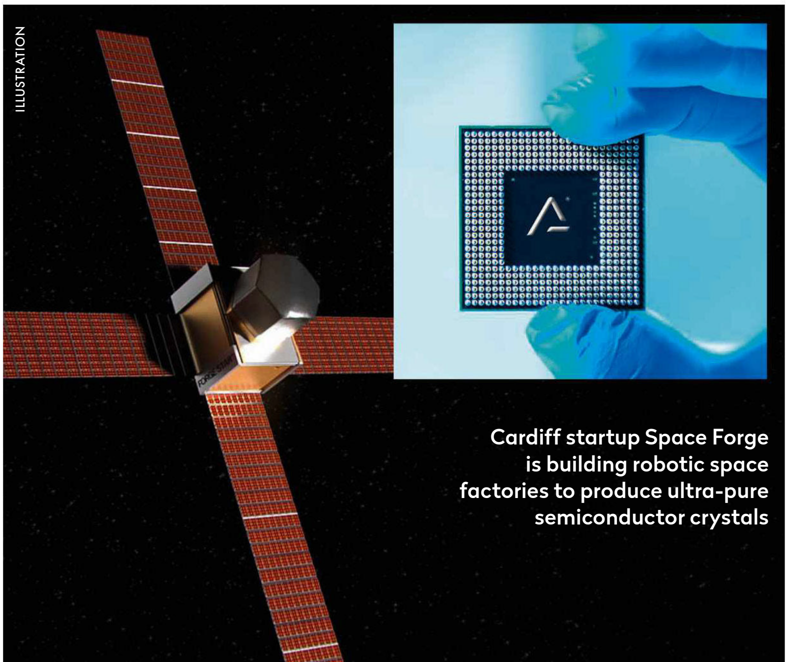
▲ Space elevators or star ladders have long been a sci-fi trope for overcoming the sticky – and expensive – problem of leaving Earth

The levels of perfection attainable in space's near-total vacuum may also produce better industrial practices and new alloys for making tinfoil or jet engines, aiding metal casting and welding. 'Containerless' processing – in which fluids and solids are manipulated at atomic levels, with acoustic or electromagnetic forces, to mitigate contamination caused by the walls of their containers – has yielded heightened levels of purity.

Commercial growth

But the space-launch landscape has now shifted, with the arrival of commercial players like Elon Musk's SpaceX and Jeff Bezos's Blue Origin. Today, there are more streamlined regulatory frameworks too, and more flexible, low-cost spacecraft platforms, including Rocket Lab's Pioneer, D-Orbit's ION Satellite Carrier and Momentus Space's Vigoride.

All that has spurred the growth of several startup firms keen to capitalise on emerging ISM commerce. Cardiff-headquartered Space Forge Ltd and its US subsidiary, Space Forge Inc, are developing free-flying facilities to make ultra-pure semiconductors in bulk for advanced computer chips, hopeful of snaring a niche in an industry projected to be worth $1 trillion in the next decade.



Cardiff startup Space Forge is building robotic space factories to produce ultra-pure semiconductor crystals

SCIENCE HISTORY IMAGES/ALAMY STOCK PHOTO, W.S. CODA/ALAMY STOCK PHOTO, SPACE FORGE X 2, BLUE ORIGIN, VARDA X 2

A planet for life alone?

The billionaire founder of Amazon and Blue Origin has a vision of the space economy's benefits to Earth

Despite Blue Origin founder Jeff Bezos's hope that all polluting industries will someday transition into space, where they'll be unable to damage Earth's biosphere, even he acquiesces the process will take many decades, if not centuries to achieve.

"In at least a few hundred years... all of our heavy industry will be moved off-planet," Bezos has said. "Earth will be zoned residential and light industrial. You shouldn't be doing any heavy energy on Earth."

▲ Earth could be shielded from heavy industry, says Jeff Bezos

Bezos envisages a future where computer chips are fabricated in colossal orbital factories and solar array farms produce energy 24/7, beaming it down to Earth; where the hugely polluting exploitation of raw materials – including precious minerals and metals of high-value worth – is moved to places where there is no ecosystem to destroy, like the Moon.

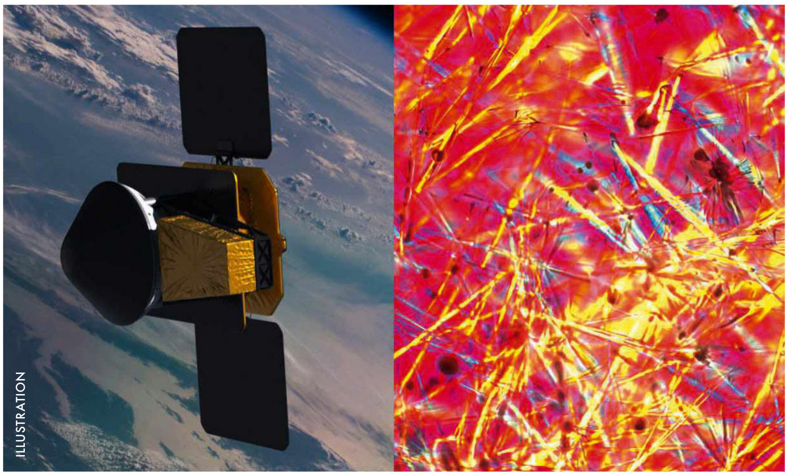
Blue Origin has taken steps to drive down the cost of reaching space with its passenger-carrying New Shepard suborbital booster, which has flown 28 times since 2015. And its gigantic New Glenn rocket, first launched in January 2025, features cleaner-burning propellants of liquified methane and can be reused for at least 25 missions.

The steps taken today by Blue Origin and others remain baby steps, and Bezos's vision of industry in deep space will doubtless not occur in our lifetimes. But reusability is a step in the right direction for making space more accessible for innovation to thrive.

New Glenn, reusable and using cleaner propellant, is key to Bezos's vision

And California-based Varda Space is tapping into high-value pharmaceutical, fibre-optic and semiconductor markets. Its first mission – W-1, which Varda called a 'space factory' – launched in June 2023, growing crystals of the antiretroviral drug ritonavir and returning them to Earth in February 2024. Rocket Lab has built four Pioneer spacecraft for Varda's missions, the second of which launched in January 2025.

Future ISM applications include extracting precious minerals from other celestial bodies, lessening the impact of mining and better safeguarding our planet's finite natural resources. Current environmental constraints (including carbon-emission limits) could accelerate the transition of highly polluting heavy industries to destinations far beyond Earth. And that might facilitate sustained growth and offset social and environmental costs as those industries move elsewhere.



▲ **Varda Space crystallised the antiviral drug ritonavir in its W-1 space factory**

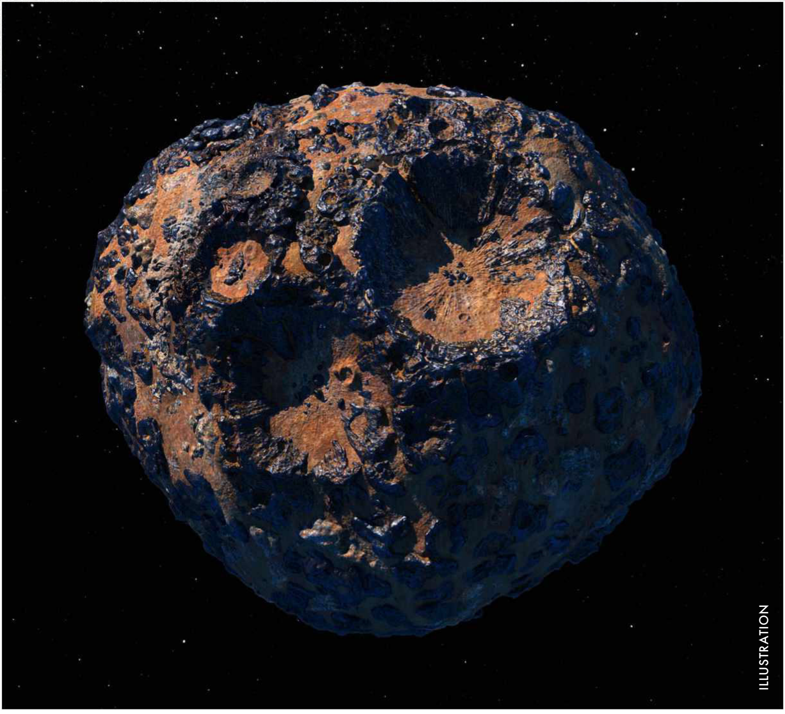
Lunar mining potential

The Moon is one such destination which could see more ISM in future decades. It is close enough to Earth to be reachable in a few days, but its low gravity, absence of an atmosphere and lack of an ecosystem leave it ripe for industrial exploitation. Viable enterprises in the future could include mining water-ice and hydrated minerals for life-support and propulsion systems, as well as extracting anorthosite from the lunar highlands to smelt for aluminium, silica to make glass and iron for stronger, more lightweight alloys.

There are also plentiful reserves of helium-3 on the Moon, which creates a potential pathway to efficient nuclear fusion. With possibly 50 parts per billion of helium-3 in its permanently shadowed lunar craters, compared to 7.2 parts per trillion in Earth's atmosphere, the Moon may have enough to satiate our planet's energy needs for thousands of years. But extracting it will be laborious – 150 tonnes of lunar soil would need to be excavated to retrieve a single gram of helium-3. ▶

Cement, water and Moon soil could be combined to build habitats and launch pads on the lunar surface

ILLUSTRATION



▲ **The metal-rich 220km-wide (140-mile) asteroid Psyche is prime drilling territory**

▶ Despite these potential difficulties, in March 2024 the US startup firm Interlune unveiled its plans to commercially mine lunar helium-3 and return it to Earth for use in national security, quantum computing, medical energy and nuclear fusion markets.

Rich pickings are also afforded by carbonaceous asteroids. Asteroid 511 Davida, for example, is estimated to possess $27 quadrillion in precious minerals, while the metal-rich 16 Psyche might have enough nickel-iron to supply industrial demands for several million years. And the Earth-crossing asteroid 3554 Amun could contain 30 times more metal than has ever been mined in human existence, with a purported 'value' in excess of $20 trillion.

In addition to valuable metals such as nickel, cobalt, gold and platinum, asteroids also provide a wealth of other volatile materials, useful for manufacturing fuels, fertilisers, water and oxygen for sustainable deep-space exploration. But capitalising on this seemingly limitless extraterrestrial bounty could prove its own showstopper – possibly producing a post-scarcity economy for many previously 'precious' minerals, but also flooding Earth's commodity markets so rapidly as to quickly make itself hideously unprofitable.

Living off the land

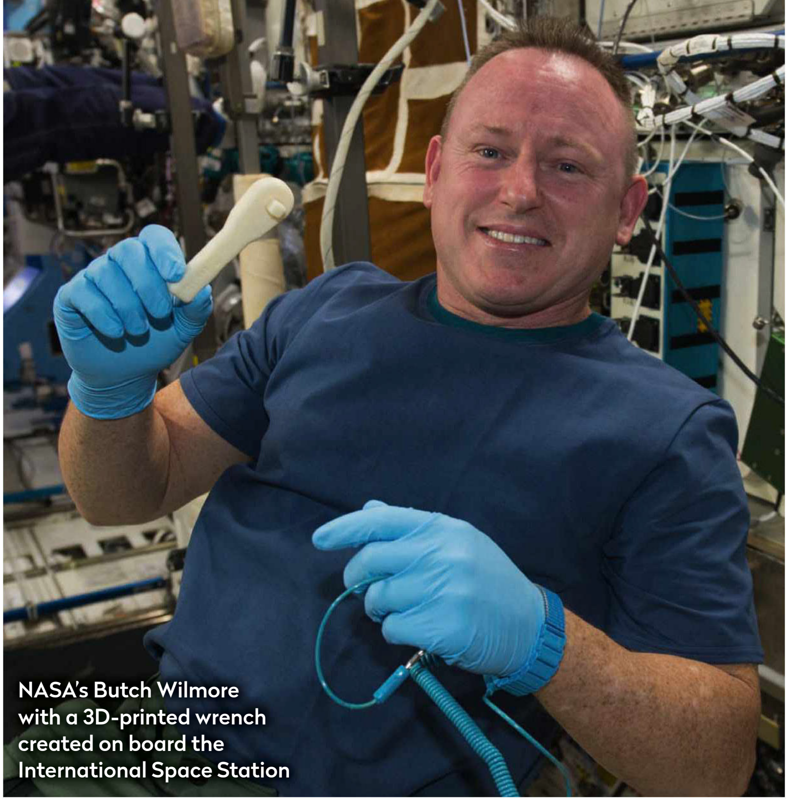
With an expectation that humans will soon return to the Moon, what's termed In-Situ Resource Utilisation (ISRU) – 'living off the land' – is imperative if future spacefaring communities are to attain self-sufficiency and independence from Earth. Lunar soil (regolith) is corrosive, highly abrasive and harmful to mechanical parts, but could be put to use as a general building material for foundations, habitats, hangars, roads and launch pads.

It can be employed to make 'concrete' (with normal cement and water, plus regolith as the aggregate) and its properties include high durability, resistance both to harmful gamma rays and to prolonged exposure to near-total vacuum, and an ability to withstand sweeping temperature extremes on the Moon's radiation-drenched surface from 120°C (250°F) in direct sunlight to –150°C (–240°F) during the frigid lunar night.

In 2023, Blue Origin and Florida-based Redwire Corp began prototyping ISM technologies for NASA to build lunar infrastructure with materials from the Moon. Redwire will heat and solidify regolith using microwave emitters, while Blue Origin's Blue Alchemist process will make solar cells and transmission wires directly from regolith – extracting iron, silicon and aluminium at temperatures of 1,600°C (2,900°F) to attain purities better than 99.999 per cent, then depositing metallic contacts to fabricate high-efficiency power-generating arrays.

Redwire launched a 3D-printed lunar regolith 'simulant' to the International Space Station (ISS) in August 2021. Last year, astronauts

ESA/FOSTER + PARTNERS, NASA/JPL-CALTECH/ASU, NASA X 2, ESA/NASA



NASA's Butch Wilmore with a 3D-printed wrench created on board the International Space Station

More esoterically, the 3D-printed artwork capturing a human laugh

successfully mixed and cured the simulant to examine its behaviour, microstructure and mechanical strength.

The orbiting testbed

Indeed, 3D printing as an ISM tool is not new. In November 2014, Florida-based Made in Space Inc, trialled a 3D printer on the ISS for the first time, allowing astronaut Barry 'Butch' Wilmore to manufacture an 11.4cm (4.48-inch) ratchet wrench. Future 3D printing is expected to enhance mission success and improve safety, facilitate in-situ repairs, enhance astronauts' self-sufficiency and reduce the dependency on resupply missions from Earth.

Since then, other 3D printers have arrived at the ISS which have printed engineered plastics and successfully produced antenna parts and adaptors for air outlets. In 2017, the first piece of sculpted artwork, a 3D model of the soundwave of a human laugh, was printed on the ISS. And in January 2024, the European Space Agency (ESA) delivered a metal 3D printer to the station to print small metallic parts.

In 2023, Redwire's Pharmaceutical In-Space Laboratory Biocrystal Optimisation Experiment (PIL-BOX) launched to the ISS to manufacture pharmaceuticals for antiviral, antifungal and antiseizure uses. It grew high-purity insulin crystals and materials to combat rheumatoid arthritis, multiple myeloma and breast and prostate cancers.

Since 2019, the ISS's BioFabrication Facility (BFF) has used 'bioinks' – composed entirely of live human cells and nutrients – to print entire human organs. This included a partial human knee meniscus in 2023 for a US military research project and, last year, the first live human heart tissue sample, with bioprinting of human blood vessels expected to follow.

Made in Space Inc and Washington-headquartered Tethers Unlimited Inc have also provided recycling equipment to the ISS since 2018, repurposing used polymer materials into new filament for 3D-printing feedstock. In 2020, the printing of temperature-resistant reinforced ceramics was evaluated for the first time. Historically, 3,200kg (7,000lb) of spare parts are transported from Earth to the ISS annually – a process acceptable in low-Earth orbit but far less feasible for deep-space missions.

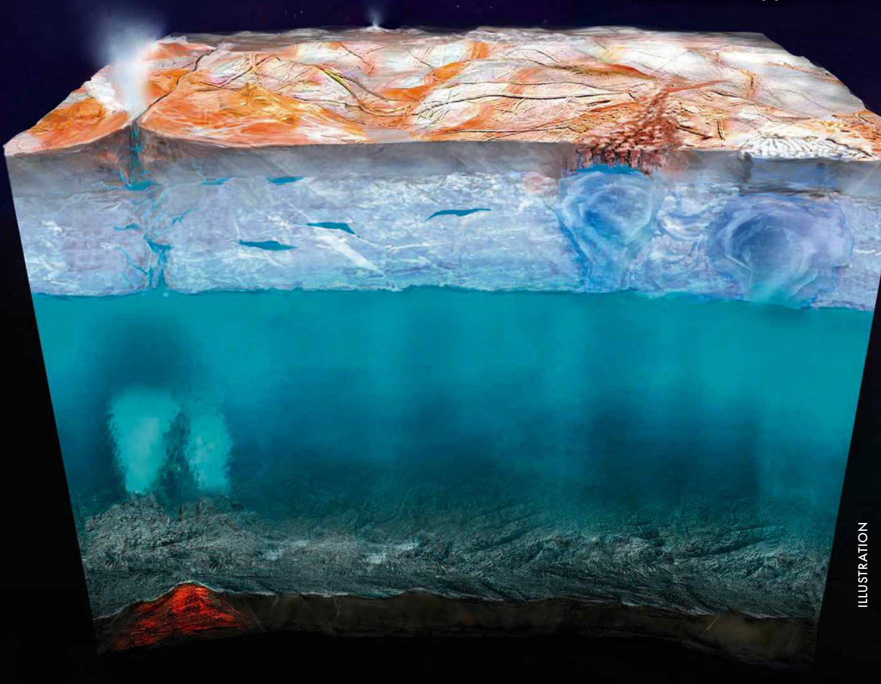
And when humans reach Mars, ISM will be critical to astronauts' self-sufficiency. NASA's Perseverance rover, which landed in Jezero Crater in February 2021, carried an experiment to extract carbon dioxide from the Red Planet's thin atmosphere and produce oxygen. The MOXIE experiment generated about 12g (0.4oz) of oxygen per hour at 98 per cent purity, considered higher than NASA's pre-flight predictions.

The costs, complexities and challenges of making ISM commonplace are immense. But it is difficult not to see the potential a century or two from now, and to let the mind drift for a moment to visualise the possibilities: bustling colonies built entirely in space, mining on the Moon and elsewhere, a post-scarcity economy – and most importantly, our own Earth, restored to the green and bountiful planet as it should be.

▲ The ISS's new metal 3D printer is a step towards manufacturing tools and parts in space

Ben Evans is a science writer and the author of several books on spaceflight

Hidden oceans and alien life


Many of Jupiter and Saturn's moons have subsurface oceans that could support life

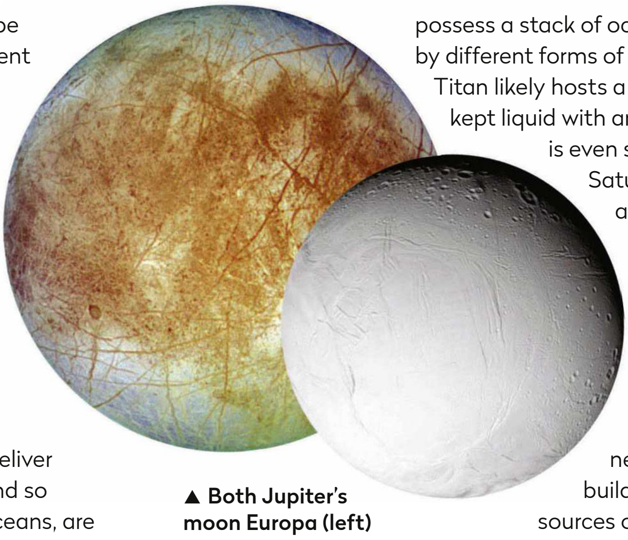
The frozen moons of the giant planets could be harbouring alien life beneath their surfaces. **Lewis Dartnell** looks at how we can discover what lurks beneath the ice

Earth is often considered to be a water world: over 70 per cent of our planet's surface is covered in oceans. Since our planet orbits within what's known as the 'Goldilocks zone' around the Sun, the warmth it receives is just right for keeping water in its liquid state. But there are several moons in the outer Solar System that are also known to hold significant bodies of liquid water.

Subsurface oceans

Beyond Earth's orbit, the Sun doesn't deliver enough warmth to keep water liquid and so these extraterrestrial oceans, or exo-oceans, are kept liquid by a different source of energy. Many of the moons orbiting the gas giant planets Jupiter and Saturn experience significant amounts of tidal heating. The gravitational pull of the parent planet causes two symmetrical bulges on the moon, which move as the moon rotates. This continual flexing of the globe creates internal friction, which is converted into heat. It's like how a rubber racquetball or squash ball warms up through being repeatedly deformed as it's thwacked around the court.

For icy moons like Europa orbiting Jupiter and Enceladus around Saturn, this tidal heating has thawed part of the frozen shell into large bodies of subsurface liquid water. Ganymede, which orbits 60 per cent further out from Jupiter than Europa, also experiences enough tidal heating for a substantial underground ocean. In fact, Ganymede might even possess a stack of ocean shells separated by different forms of ice. Saturn's giant moon Titan likely hosts a water ocean beneath its crust, kept liquid with ammonia antifreeze. And there is even some evidence that another Saturnian satellite, Mimas, as well as a small moon of Uranus, Miranda, may have previously contained a subsurface ocean.


▲ **Both Jupiter's moon Europa (left) and Saturn's moon Enceladus (right) have global oceans of liquid water under an icy shell**

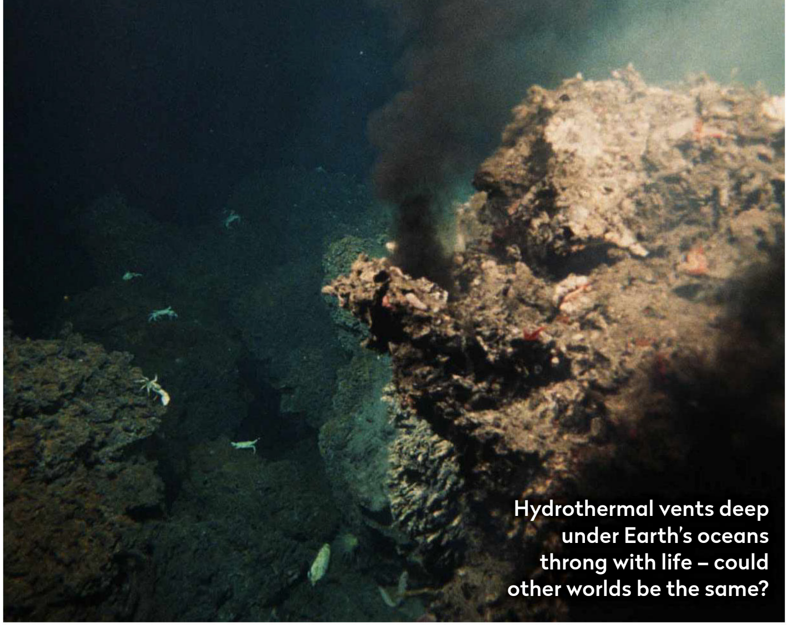
Liquid water is required for all life on Earth, so might some of these exo-oceans also harbour alien life? Water alone is not enough; life also needs organic chemistry to build its complex molecules, and sources of energy in its environment. Hydrothermal vents on the seafloor provide chemical energy supporting ecosystems in the dark depths of Earth's own oceans, and so it's thought crucial that, in order to support life, the bottom of an exo-ocean must be in contact with the moon's rocky mantle. So Europa and Enceladus are thought to be the most promising candidates.

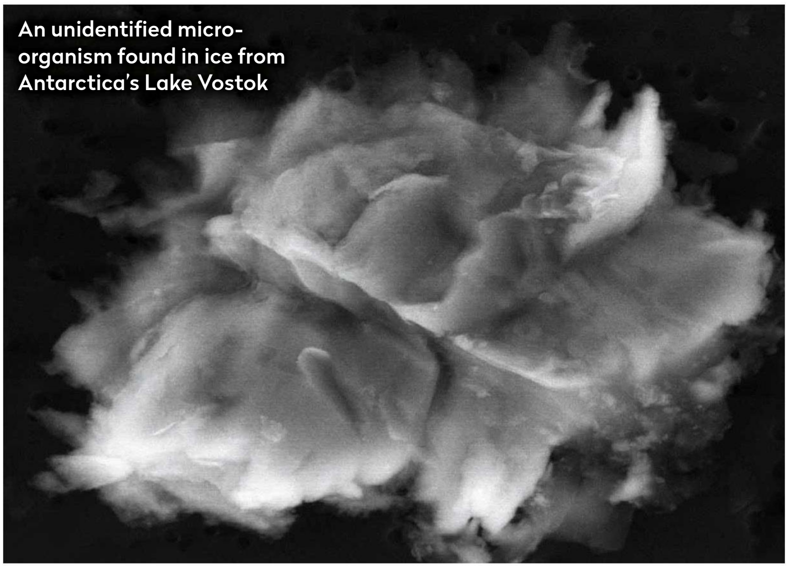
Exploring the icy moons

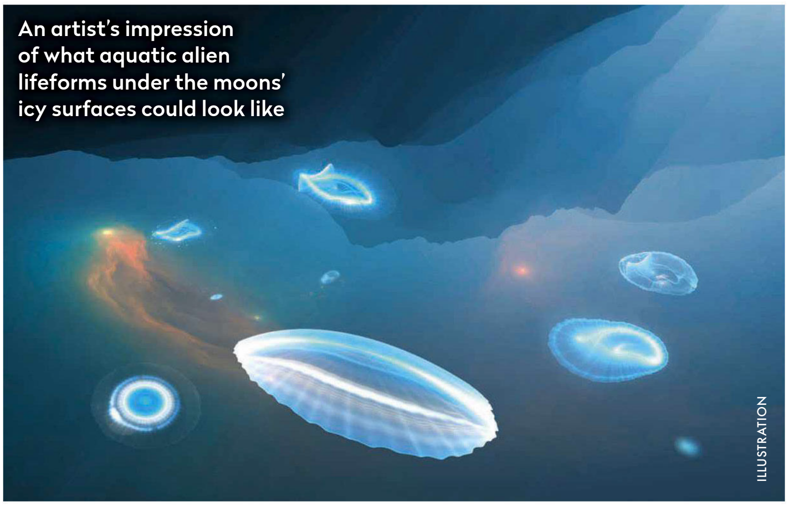
One of the major drivers for space exploration is astrobiology – the search for life beyond Earth. Plenty of orbital probes and rovers have been sent to Mars, partly because it's relatively easy to get to, but there are also exciting missions on their way to Jupiter and its moons.

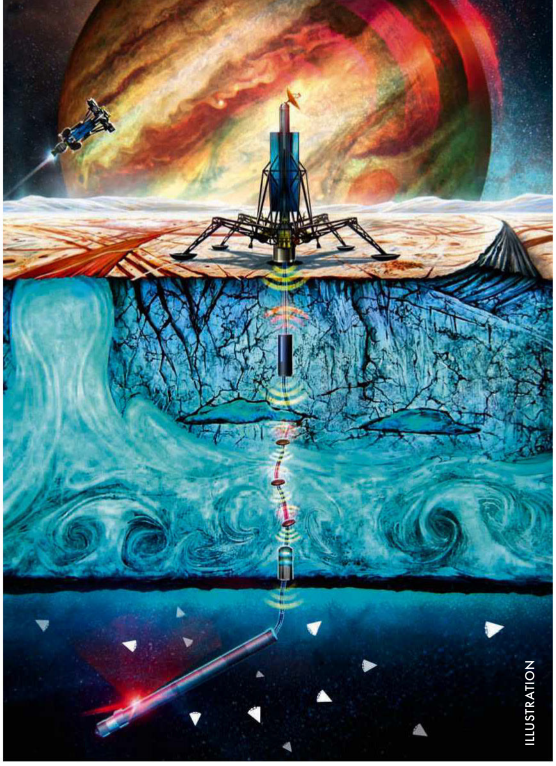
ESA's Juice (Jupiter Icy Moons Explorer) mission launched in April 2023 and will arrive at the Jovian

NASA/JPL-CALTECH X 2, NASA/JPL/DLR, NASA/JPL/SPACE SCIENCE INSTITUTE, RALPH WHITE/GETTY, SCIENCE HISTORY IMAGES/ALAMY STOCK PHOTO, PETER JURIK/ALAMY STOCK PHOTO,


Hydrothermal vents deep under Earth's oceans throng with life – could other worlds be the same?


An unidentified micro-organism found in ice from Antarctica's Lake Vostok


An artist's impression of what aquatic alien lifeforms under the moons' icy surfaces could look like



▲ **Plans are under way for landers that melt through the miles of ice and release cryobots to study the oceans**

system in July 2031. It will fall into orbit around Ganymede in December 2034, but will have two close fly-bys of Europa before that. Juice carries a ground-penetrating radar that will hopefully reveal the thickness of the ice shell above Europa's ocean, as well as other instruments that will map salts and, potentially, organic molecules on the surface.

NASA's Europa Clipper probe launched in October 2024 and will begin a series of almost 50 close approaches of Europa in April 2030. This mission will also be investigating the potential habitability of the moon, as well as looking out for plumes where water is squirting out into space. It will also help identify the best landing site for a proposed future Europa Lander. Such a mission would touch down on the moon and search for signs of oceanic life preserved in the surface ice. In the future, there are proposals to develop a 'cryobot' able to melt its way through the surface ice of Europa or Enceladus and then release autonomous submersibles to explore the ocean.

What life might exist?

We know from studying hardy 'extremophile' microbes on Earth that life can tolerate an incredible range of conditions, and feed itself on inorganic energy sources like iron and sulphur gushing out of hydrothermal vents. Lake Vostok is a body of water 4km (2.5 miles) beneath the Antarctic ice sheet, thought to be completely sealed off from the rest of the world. It's therefore taken to be a close analogue of the subsurface environment on Europa or Enceladus.

Drilling studies have identified the DNA of numerous microbes which, if not introduced via contamination from the surface, would bolster the hope of finding life in the icy moons. If the subsurface oceans in Europa and Enceladus are habitable environments, the sort of life they could host is almost certainly only simple single cells like bacteria.

However, some scientists argue that there's enough oxygen created in the surface ice, which could be transported down into the ocean beneath, to support more complex, multicellular lifeforms. So perhaps someday in the future, you'll be able to visit an aquarium to gaze upon Europan jellyfish…

Over recent decades of space exploration, we've realised that Earth is far from being the only water world in the Solar System. Europa and Enceladus contain not only subsurface oceans, but also hold the possibility of finding extraterrestrial life. And missions already en route to the Jupiter system promise some really exciting discoveries.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

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Beginning over the Arctic Ocean, the eclipse will first touch land in Greenland, where some of the most breathtaking views of totality will occur. Our ship Ambition will be strategically anchored off the coast of south-east Greenland allowing our guests some of the best views of this exciting phenomenon.

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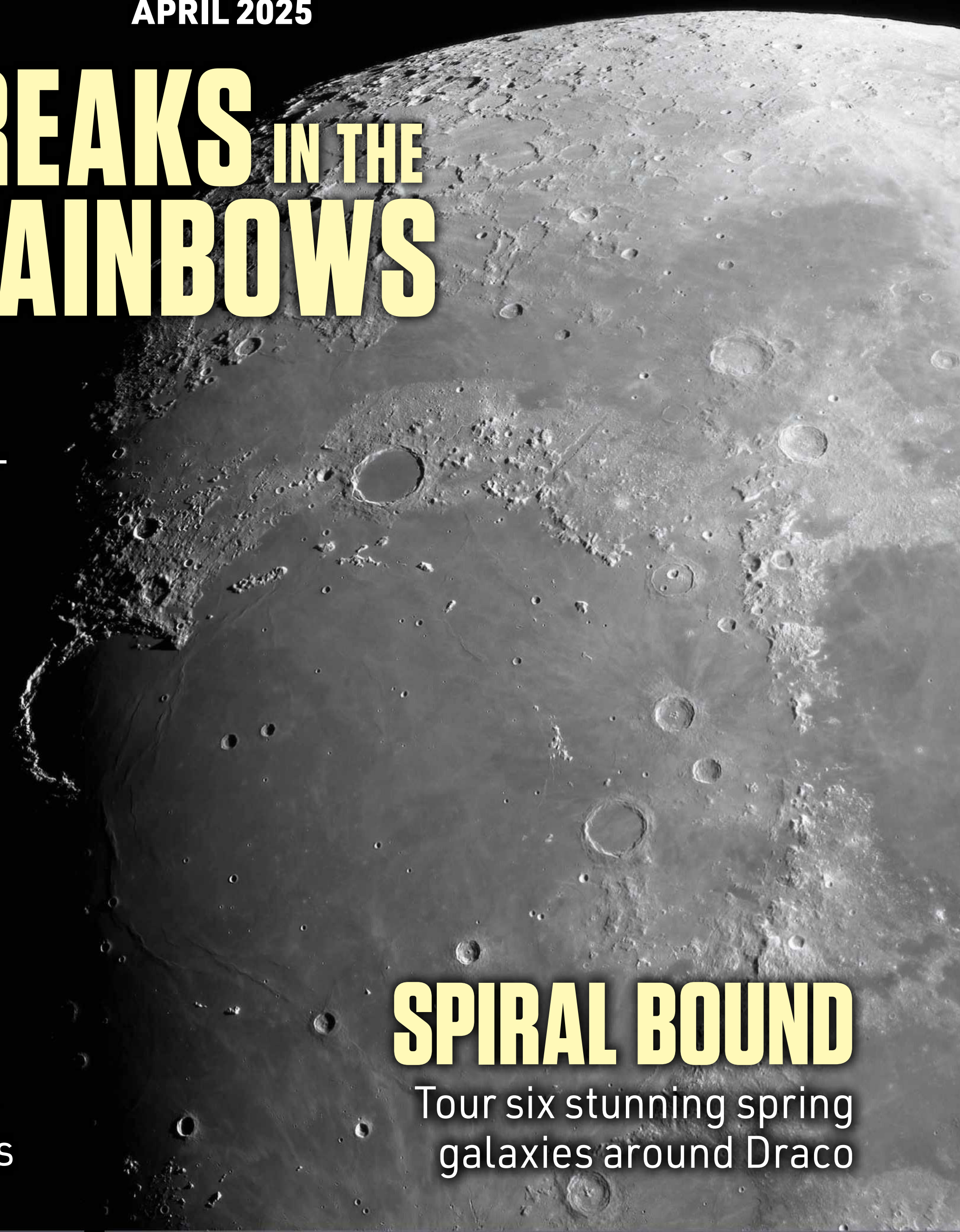
16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

APRIL 2025



PETE LAWRENCE

DAWN BREAKS IN THE BAY OF RAINBOWS

Early Moon phases this month offer the ideal time to spot clair-obscur effects like the Jewelled Handle

LUNAR RENDEZVOUS

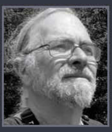
Watch the Moon cross paths with four planets

SPIRAL BOUND

Tour six stunning spring galaxies around Draco

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Lyrids meteor shower
- Asteroid 8 Flora crosses the Hamburger Galaxy
- Lunar occultation of the Pleiades
- Vesta heads into Virgo

Red light friendly

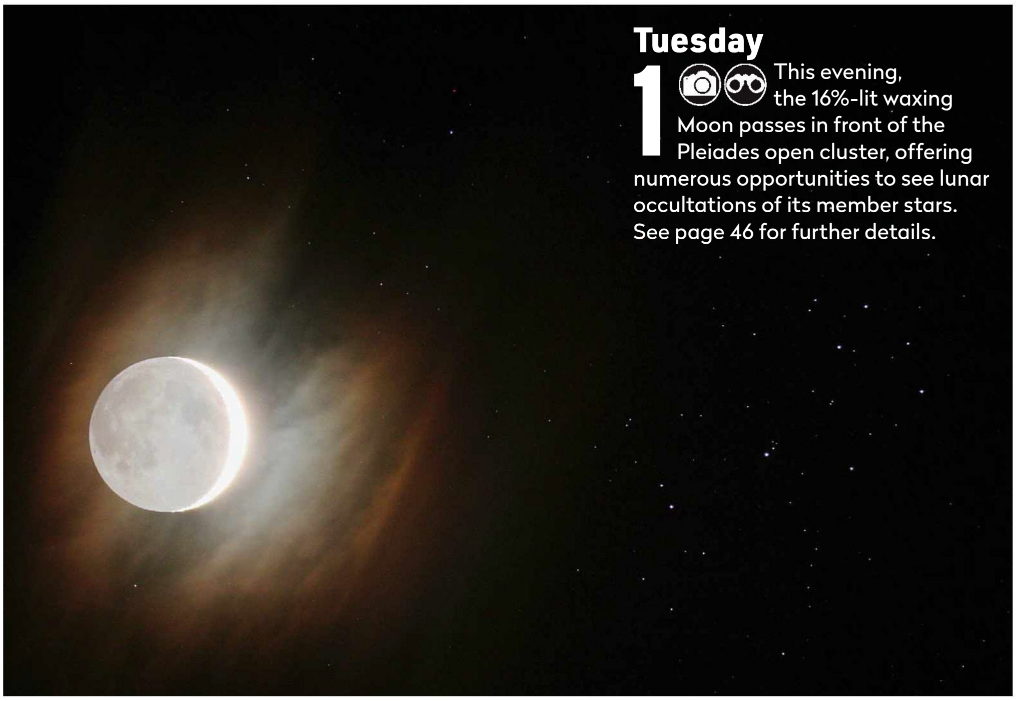
To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

APRIL HIGHLIGHTS

Your guide to the night sky this month



Tuesday

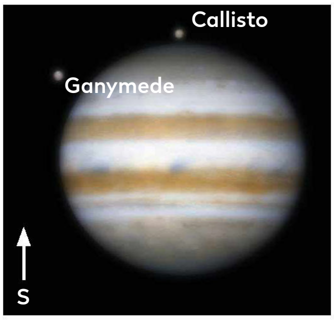
1 This evening, the 16%-lit waxing Moon passes in front of the Pleiades open cluster, offering numerous opportunities to see lunar occultations of its member stars. See page 46 for further details.

Wednesday

2 Around midnight, the 26%-lit waxing crescent Moon sits slightly under 5° north of mag. –2.0 Jupiter. Closest approach is around 00:30 BST on 3 April (23:30 UT on 2 April).

Wednesday ▶

9 Minor planet 8 Flora begins to cross the side-on spiral galaxy NGC 3628, the Hamburger Galaxy, one of the Leo Triplet. See page 47 for more details.



◀ Wednesday

16 Callisto almost appears to clip Jupiter's southern pole at 22:40 BST (21:40 UT).

◀ Thursday

17 An early taste of summer as the bright red supergiant Antares (Alpha (α) Scorpius) can be seen 1.8° northwest of the rising 85%-lit waning gibbous Moon around 01:40 BST (00:40 UT).

Friday ▶

25 Brilliant mag. –4.4 planet Venus sits 3.1° northwest of the 10%-lit waning crescent Moon this morning, both visible around 05:00 BST (04:00 UT) shortly after rising. Mag. +0.8 Saturn sits 1.7° south of the Moon's centre at this time.

Saturday

26 Low in the east at around 05:30 BST (04:30 UT) is a tricky pairing of the 3%-lit crescent Moon and mag. +3.3 Mercury 5.1° to its southwest. Take care if using binoculars, as sunrise occurs around 05:50 BST (04:50 UT).

Monday

28 Mag. –4.4 Venus sits 3.7° north of mag. +0.8 Saturn this morning, best seen around 05:15 BST (04:15 UT) in the brightening dawn twilight.

Tuesday

29 There's an extremely tricky and unusual Titan shadow transit from 11:22 BST (10:22 UT) until Saturn sets at around 16:20 BST (15:20 UT) today. The shadow crosses Saturn's disc immediately south of where the rings appear to cross the planet.

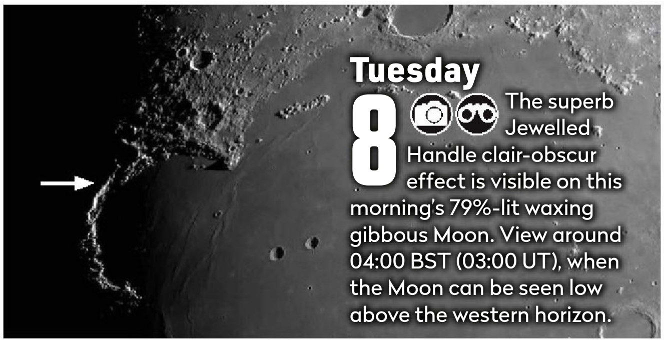
PETE LAWRENCE X 7

Saturday

5

Mag. +0.5 Mars lies 1.6° south of 58%-lit waxing Moon this evening.

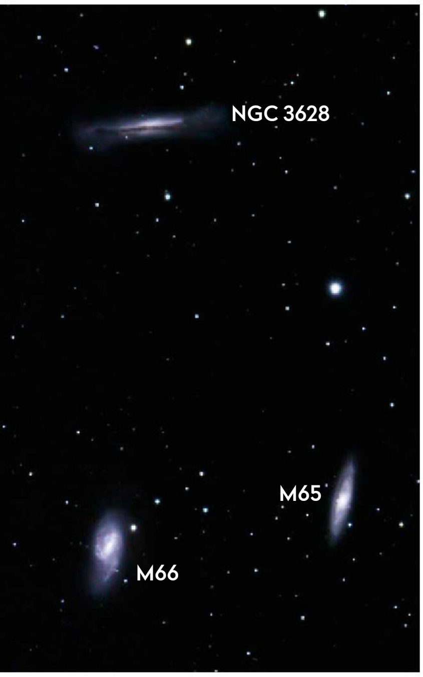
Clair-obscur events visible: Lunar X and V 13:00 BST (12:00 UT), Nessie (Ptolemaeus crater) 22:40 BST (21:40 UT), Face in Albategnius 20:55 BST (19:55 UT).



Tuesday

8

The superb Jewelled Handle clair-obscur effect is visible on this morning's 79%-lit waxing gibbous Moon. View around 04:00 BST (03:00 UT), when the Moon can be seen low above the western horizon.



Thursday

10

Mag. +0.7 Saturn, +1.2 Mercury, –4.3 Venus and +7.9 Neptune are in a 9° morning twilight circle.

The Star-Tip Mountain (Mons Herodotus) clair-obscur event is visible at 01:00 BST (00:00 UT).

Sunday

13

The bright mag. +1.0 star Spica (Alpha (α) Virginis) sits 1.1° north of the full Moon's centre at 02:36 BST (01:36 UT).

Monday

21

Shining at mag. +0.5 in the dawn twilight, Mercury reaches greatest western elongation today, separated from the Sun by 27.4°.

Tuesday

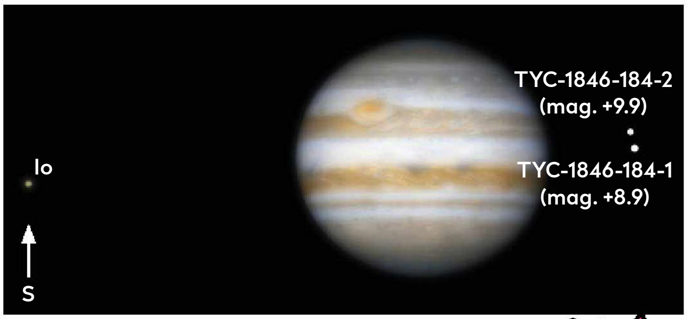
22

Today sees the annual Lyrid meteor shower reach its peak at around 14:00 BST (13:00 UT), meaning that the best observing times are this morning and from darkness this evening through to dawn on 23 April.

Sunday ▶

27

A view of Jupiter just before it sets this morning shows two stars close to its western limb: mag. +8.9 TYC 1846-184-1 and +9.9 TYC 1846-184-2. The stars are occulted around 00:05 BST (23:05 UT on 26 April).



Wednesday

30

As darkness falls, the 13%-lit waxing crescent Moon sits 5° north of mag. –1.8 Jupiter, both objects clearly visible to the naked eye above the west-northwest horizon.

Family stargazing

There's a chance for youngsters to take in the beauty of several lunar conjunctions this month. The Moon can be seen near bright Jupiter on 2 April and then near Mars on 5 April. An early morning viewing session on 25 April will show the Moon near bright Venus in the dawn twilight, with a tricky encounter between a very thin lunar crescent and Mercury on the morning of 26 April, again in the dawn twilight. Then, at the end of the month, having moved completely around the sky, the Moon and Jupiter can be seen together once again as darkness falls early evening. **www.bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly Objects marked with this icon are perfect for showing to children

Naked eye Allow 20 minutes for your eyes to become dark-adapted

Photo opp Use a CCD, planetary camera or standard DSLR

Binoculars 10x50 recommended

Small/ medium scope Reflector/SCT under 6 inches, refractor under 4 inches

Large scope Reflector/SCT over 6 inches, refractor over 4 inches

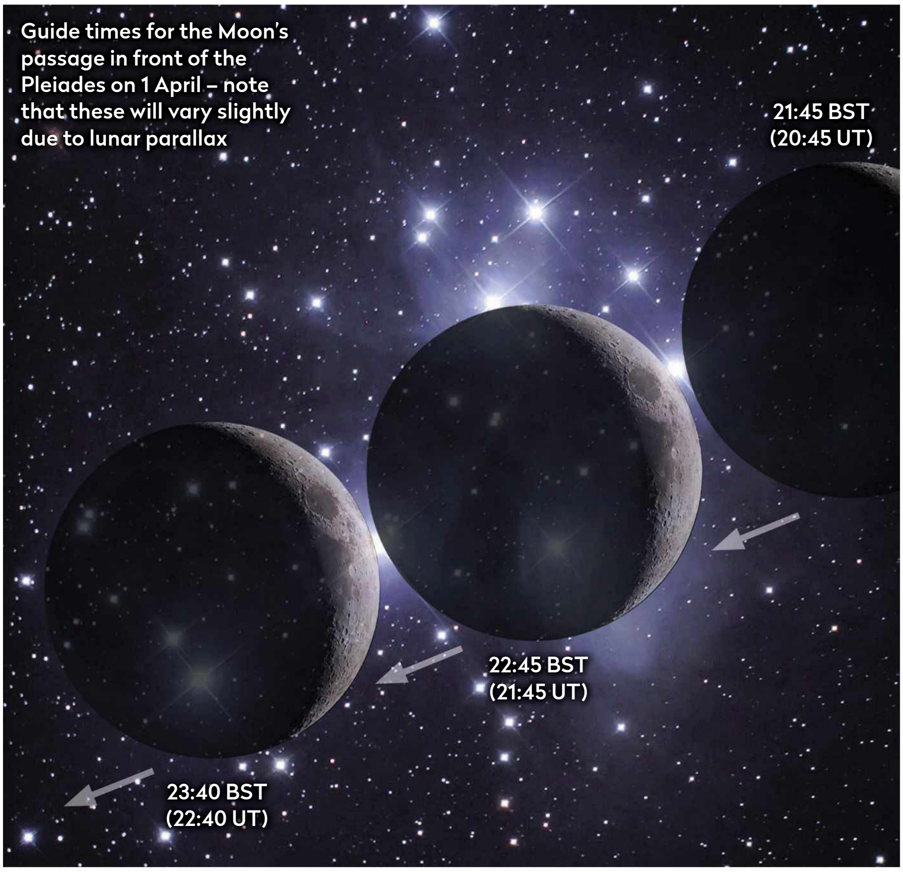
GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/stargazing-top-tips** to learn how to stargaze in 12 easy steps and **bit.ly/choose-first-telescope** for advice on choosing your first scope

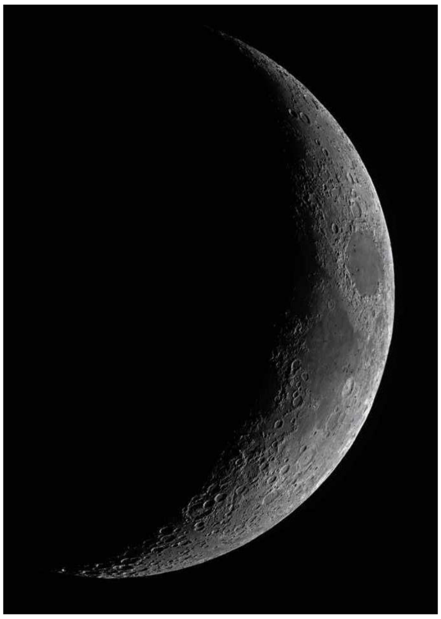
DON'T MISS

Lunar occultation of the Pleiades

BEST TIME TO SEE: 1 April from 21:15 BST (20:15 UT)



Guide times for the Moon's passage in front of the Pleiades on 1 April – note that these will vary slightly due to lunar parallax



▲ **The Moon's phase will be 16%-lit (4.1 days old waxing) at the time of the occultation**

The Moon has been skirting close to the Pleiades open cluster for several months, sometimes passing across some of its outer members. However, on 1 April, starting under conditions of deep twilight, from the vantage location of the UK the waxing crescent Moon will pass right across the cluster's core, occulting most of the brighter members.

Conditions for this are ideal for the UK, the occultation beginning at the start of the month when the Pleiades still have a decent altitude as darkness falls. For example, on 1 April at 21:00 BST (20:00 UT) under darkening twilight, the Pleiades are 30° above the western horizon. At the end of the month, under similar lighting conditions at 22:20 BST (21:20 UT), their altitude drops to just 4°.

The Moon will be at a 16%-lit waxing phase on 1 April, again ideal for the occultation as the brightness of the fully illuminated portion of the Moon's disc won't be sufficient to drown the brighter cluster stars and, consequently, the Moon's approach to the Pleiades should be just about visible with the naked eye.

Of course, binoculars will show the approach and occultations really well, as will a small telescope using a low-power eyepiece. A high magnification can be used to view the individual occultation events, but you will lose the overall context of the cluster.

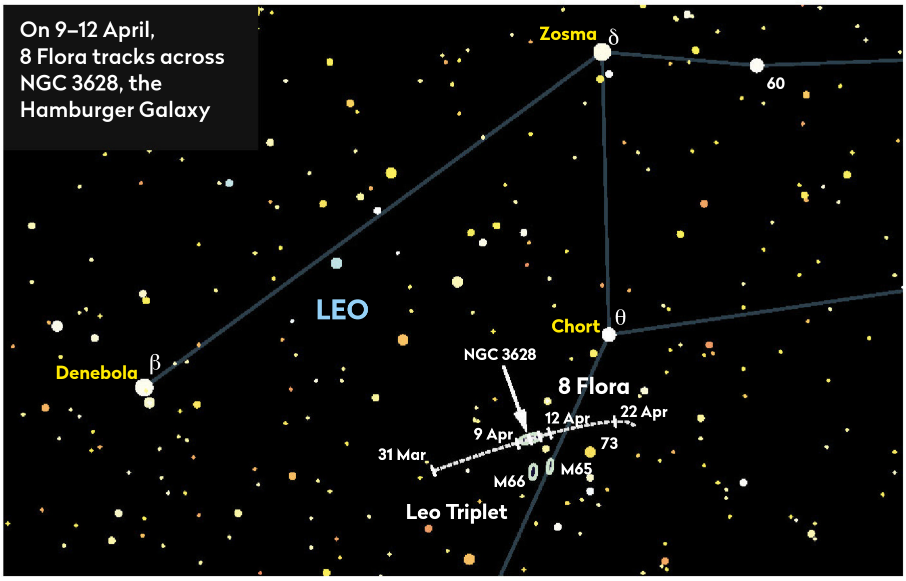
The Pleiades cluster is 444 lightyears from Earth. The Moon, on the other hand, is much closer at around 360,000km away at the time of the occultation. As a consequence, different locations within the UK experience different occultation timings, due to lunar parallax: the apparent shift in the Moon's position relative to a more distant body when seen from varying locations. The timings shown above are for the centre of the UK. Those who live further north will see the Moon's apparent position shift further south relative to the cluster; those to the south will see the Moon shift slightly north.

If the weather doesn't work out, there are plenty of other Moon-related events to see this month, including several Moon–planet conjunctions and several interesting clair-obscur events. For example, on 6 April at 03:00 BST (02:00 UT), there's the Stars of Aristillus, a lunar dawn event where mountain peaks in the crater Aristillus resemble a star cluster. The Eyes of Clavius effect is visible later that day around 18:35 BST (17:35 UT) and Plato's Hook at 23:40 BST (22:40 UT), also on 6 April. We've listed several more in our calendar on pages 44–45.

ALL PICTURES: PETE LAWRENCE

Flora crosses the Leo Triplet

BEST TIME TO SEE: 9–12 April



On 9–12 April, 8 Flora tracks across NGC 3628, the Hamburger Galaxy

Back in February's issue, our Sky Guide Challenge was to track a couple of asteroids heading towards deep-sky objects. The asteroids were 28 Bellona, which passed through the Beehive Cluster towards the end of March, and 8 Flora, which is due to pass through the Leo Triplet, the iconic grouping of three galaxies in the back leg of Leo, the Lion, during the first half of April.

The Leo Triplet consists of three spiral galaxies, each with its own distinct shape: mag. +10.5 M65, mag. +10.0 M66 and mag. +9.5 NGC 3628. It's the lowest-surface-brightness galaxy, NGC 3628, which will have the honour of 8 Flora passing in front of it between 9 and 12 April, the asteroid appearing as a mag. +10.1 star-like dot.

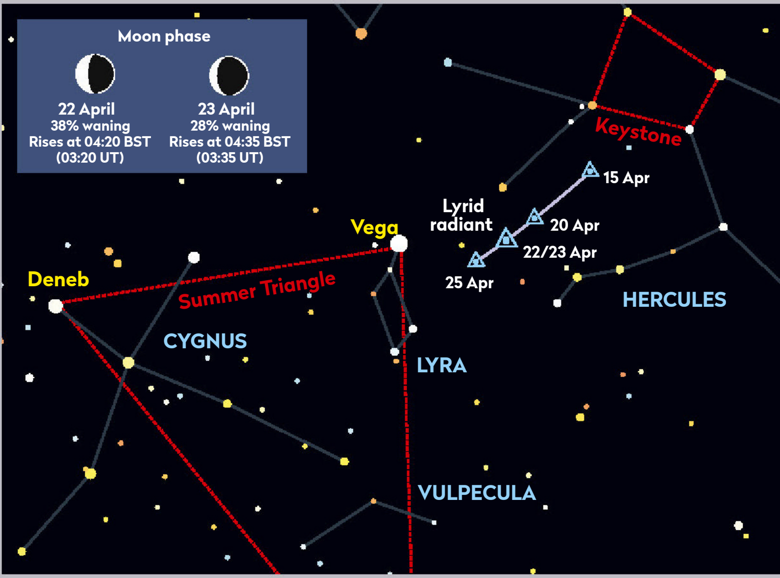
NGC 3628 is informally known as the Hamburger Galaxy due to its physical make-up and sideways-on orientation to Earth. A dark and relatively thick dust lane crosses the galaxy, appearing as the burger sandwiched between brighter portions of the galaxy either side of it. Along with having less surface brightness than the other two members of the triplet, NGC 3628 also appears more rectangular.

The crossing will best suit small or large telescopes and is an ideal event to try to record photographically. Smart telescopes should pick up hamburger-shaped NGC 3628 quite well and mag. +10.1 Flora is well within their imaging capabilities.

If you prefer more traditional methods, Flora's location within the Leo Triplet should make visual identification easy. Take your time and make a detailed sketch of the galaxy before the crossing starts, using the sketch as a reference for marking the position of Flora on the days it makes its pass.

Lyrid meteor shower

BEST TIME TO SEE: Nights of 21/22 and 22/23 April



▲ The Moon won't interfere with this year's Lyrids peak

After the Quadrantid meteor shower in early January, there's been a lull in significant meteor activity until this month. The Lyrids meteor shower is active between 16 and 25 April, with the 2025 peak predicted for 14:00 BST (13:00 UT) on 22 April. As a result, the best rates are likely during a dawn watch on the morning of 22 April and an all-night watch starting later the same day.

The Lyrids occur when Earth passes through the dust debris stream strewn around the orbit of comet C/1861 G1 Thatcher. At its peak, the shower produces a ZHR of around 18 meteors per hour. The waning crescent Moon rises as dawn is underway, so won't interfere this year.

A meteor shower's visual hourly rate is affected by the altitude of the shower radiant (the area of sky from which the shower's trails appear to emanate). For the Lyrids, this reaches a peak altitude at dawn, rising over 60° above the southern horizon. Unusually, the Lyrid peak doesn't actually occur within the constellation Lyra, but rather within neighbouring Hercules. The apparent misnaming occurs because the shower was named before the modern official constellation borders were drawn up by the International Astronomical Union, the peak originally being associated with Lyra.

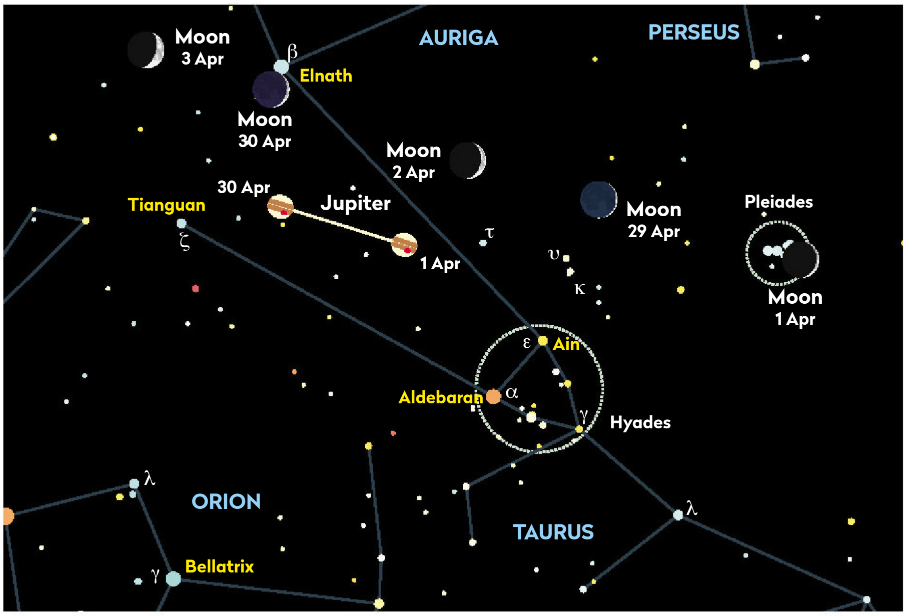
THE PLANETS

Our celestial neighbourhood in April

PICK OF THE MONTH

Jupiter

Best time to see: 1 April, 21:00 BST (20:00 UT)
Altitude: 40°
Location: Taurus
Direction: West-southwest
Features: Complex atmosphere, satellites
Recommended equipment: 75mm or larger



Moon
3 Apr
β
Elnath
AURIGA
PERSEUS
Moon
30 Apr
Moon
2 Apr
30 Apr
Tianguan
Jupiter
ζ
τ
1 Apr
Moon
29 Apr
Pleiades
υ
κ
Moon
1 Apr
ε
Ain
Aldebaran
α
γ
Hyades
λ
ORION
TAURUS
λ
γ
Bellatrix

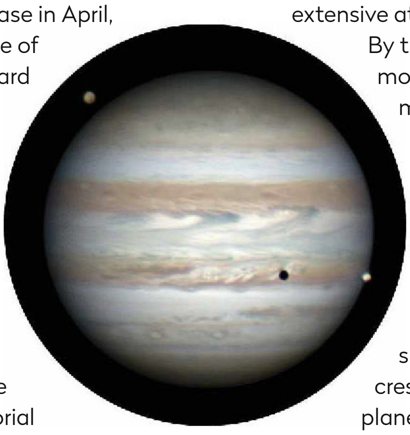
▲ Jupiter is slowly heading east towards the tips of Taurus's horns this month

Jupiter's observing window slowly closes this month, thanks to the planet's move closer to the Sun combined with the expanding evening twilight.

On 1 April, Jupiter shines at mag. –2.0 and is positioned 40° above the west-southwest horizon as evening twilight darkens. A 16%-lit waxing crescent Moon can be seen further to the west of Jupiter (down and right as seen from the UK) that evening. On the evening of 2 April, a 25%-lit lunar crescent will now be quite close to brilliant Jupiter. As the pair approach setting at around 01:30 BST (00:30 UT) on 3 April, the Moon will be located 4.7° north of the planet.

For many weeks, Jupiter has been located within Taurus, the Bull, close to the star Aldebaran and the Hyades open cluster. This is still the case in April, but there's now evidence of the planet's slow eastward movement towards the two stars that mark the bull's horn tips: Elnath (Beta (β) Tauri) and Tianguan (Zeta (ζ) Tauri).

Jupiter's atmosphere has been interesting of late too, with a lot of disturbance within the south equatorial belt (SEB). Appearing as a series of distorting white spots, these were quite extensive at the start of 2025. By the end of the month, Jupiter is in a much less tenable state, just 18° above the western horizon at 22:00 BST (21:00 UT) as darkness is falling. The Moon rejoins Jupiter on the evening of 30 April, a slender 6%-lit waxing crescent 13.5° west of the planet. Jupiter now appears much closer to the bull's horn tips than it did at the start of April.

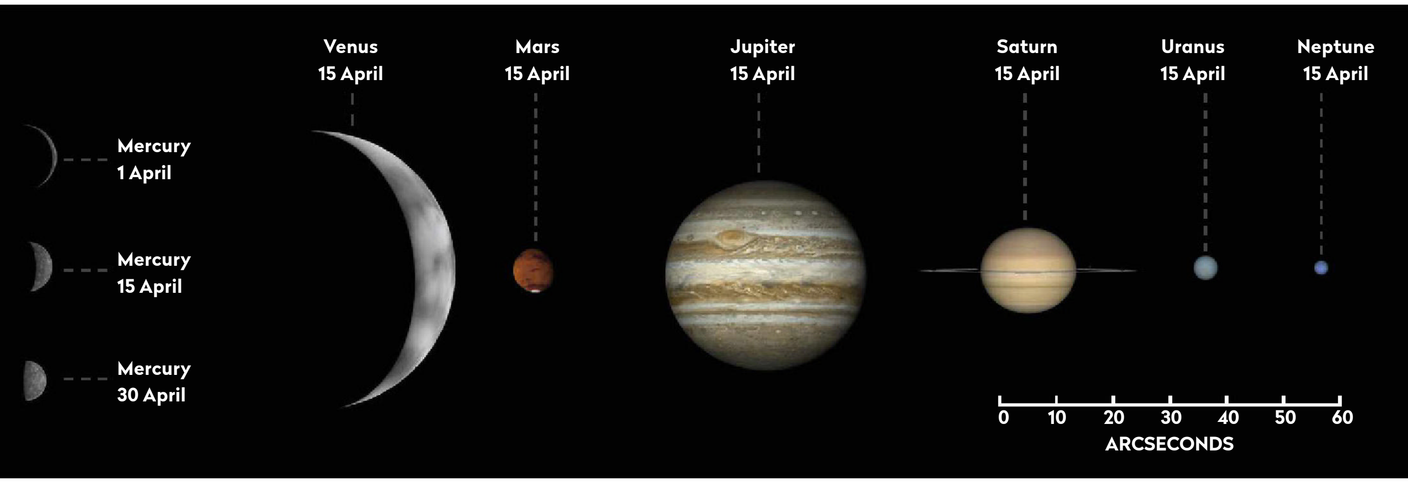


▲ Distorted white spots (near Io's shadow) in the south equatorial band

PETE LAWRENCE X 2

The planets in April

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



Venus
15 April
Mars
15 April
Jupiter
15 April
Saturn
15 April
Uranus
15 April
Neptune
15 April
Mercury
1 April
Mercury
15 April
Mercury
30 April
0
10
20
30
40
50
60
ARCSECONDS

Mercury

Mercury is a morning planet this month, reaching an impressive greatest western elongation, separated from the Sun by 27.4° on 21 April. Despite this, the planet's position is not good from the UK and consequently it's unlikely to be visible this month.

Venus

Best time to see: 30 April, 30 minutes before sunrise
Altitude: 6° (low)
Location: Pisces
Direction: East

Along with several other planets, Venus can be found in the morning sky this month. On 1 April, Venus rises at 05:40 BST (04:40 UT), some 70 minutes before the Sun. It's a bright object shining at mag. –4.1 and, having passed inferior conjunction last month, remains large with a small phase. On 1 April, through the eyepiece of a telescope Venus appears 56 arcseconds across and 3% lit, a beautifully slender crescent. By the end of the month, having brightened to mag. –4.4, Venus appears 36 arcseconds across with a phase of 28%.

On the morning of 25 April, a 10%-lit waning crescent Moon sits inside the small triangle formed by Venus, Saturn and Neptune, the Moon 3.2° southeast of Venus.

Mars

Best time to see: 1 April, 21:10 BST (20:10 UT)
Altitude: 59°
Location: Gemini
Direction: South

Mars is the best-placed planet this month, remaining at a decent altitude in dark skies throughout April. This is not to say it's ideally placed though, because at the end of the month, it loses altitude to the expanding evening twilight.

On 1 April, mag. +0.5 Mars appears 59° above the southern horizon at 21:10 BST (20:10 UT), an ideal position for observation. Now distancing itself from Earth, the planet is only 8 arcseconds across at this time, so good, steady seeing is required to see any serious detail. On 5 April, at 21:10 BST (20:10 UT), Mars is 1.6° south of the 57%-lit waxing gibbous Moon.

By the end of the month, twilight makes its presence felt but despite a noticeable rush to the east into Cancer and towards the Beehive Cluster, M44, Mars remains 40° up above the west-southwest horizon as darkness is falling.

Saturn

Best time to see: 30 April, 05:00 BST (04:00 UT)
Altitude: 2° (extremely low)
Location: Pisces
Direction: East

Saturn is a mag. +0.8 morning planet but extremely hard to see due to its low altitude in bright twilight. On 23 April, it sits 4.5° south-southeast of Venus.

Uranus

Best time to see: 1 April, 21:45 BST (20:45 UT)
Altitude: 17°
Location: Taurus
Direction: West

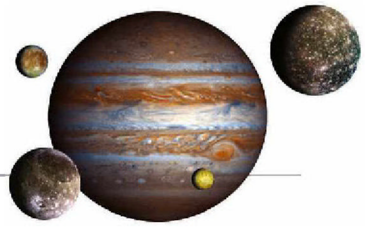
Mag. +5.8 Uranus is an evening planet losing the battle with the evening twilight this month. It's lost from view in the second half of April.

Neptune

Not visible this month.

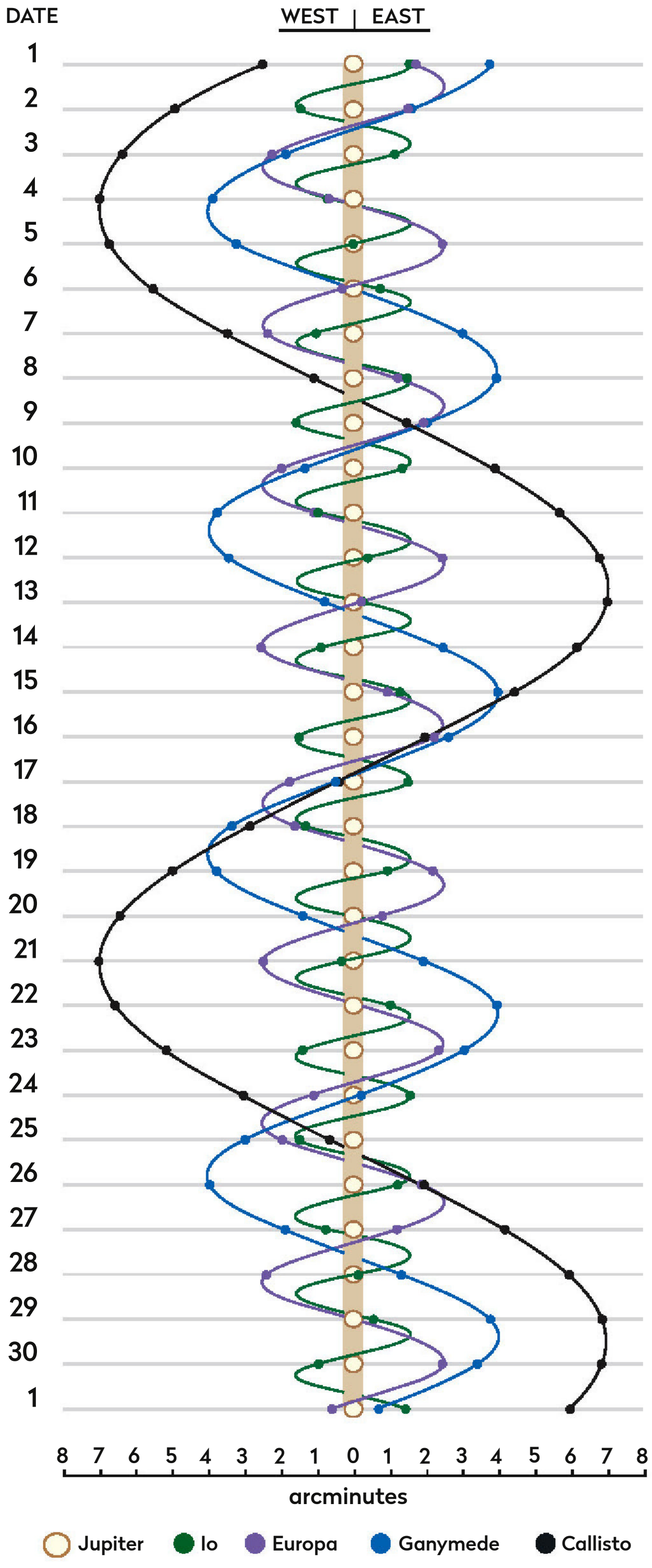
FREE BONUS CONTENT

Print planet observing forms www.skyatnightmagazine.com/bonus-content



JUPITER'S MOONS: APRIL

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – APRIL

Explore the celestial sphere with our Northern Hemisphere all-sky chart

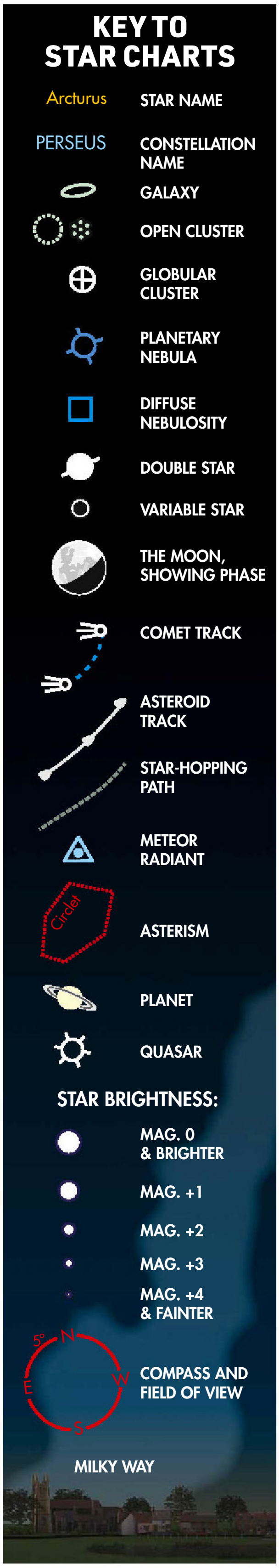

KEY TO STAR CHARTS
Arcturus
STAR NAME
PERSEUS
CONSTELLATION NAME
GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
THE MOON, SHOWING PHASE
COMET TRACK
ASTEROID TRACK
STAR-HOPPING PATH
METEOR RADIANT
Circlet
ASTERISM
PLANET
QUASAR
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER
5°
N
E
W
S
COMPASS AND FIELD OF VIEW
MILKY WAY

CHART: PETE LAWRENCE

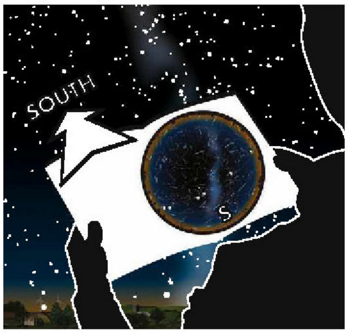
When to use this chart

1 April at 01:00 BST
15 April at 00:00 BST
30 April at 23:00 BST

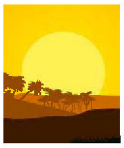
On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.



Sunrise/sunset in April*



Date	Sunrise	Sunset
1 Apr 2025	06:43 BST	19:45 BST
9 Apr 2025	06:23 BST	20:00 BST
17 Apr 2025	06:05 BST	20:14 BST
25 Apr 2025	05:47 BST	20:29 BST

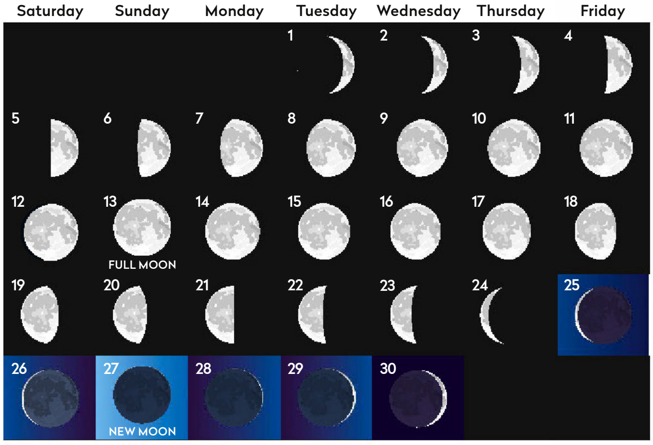
Moonrise in April*

Moonrise times

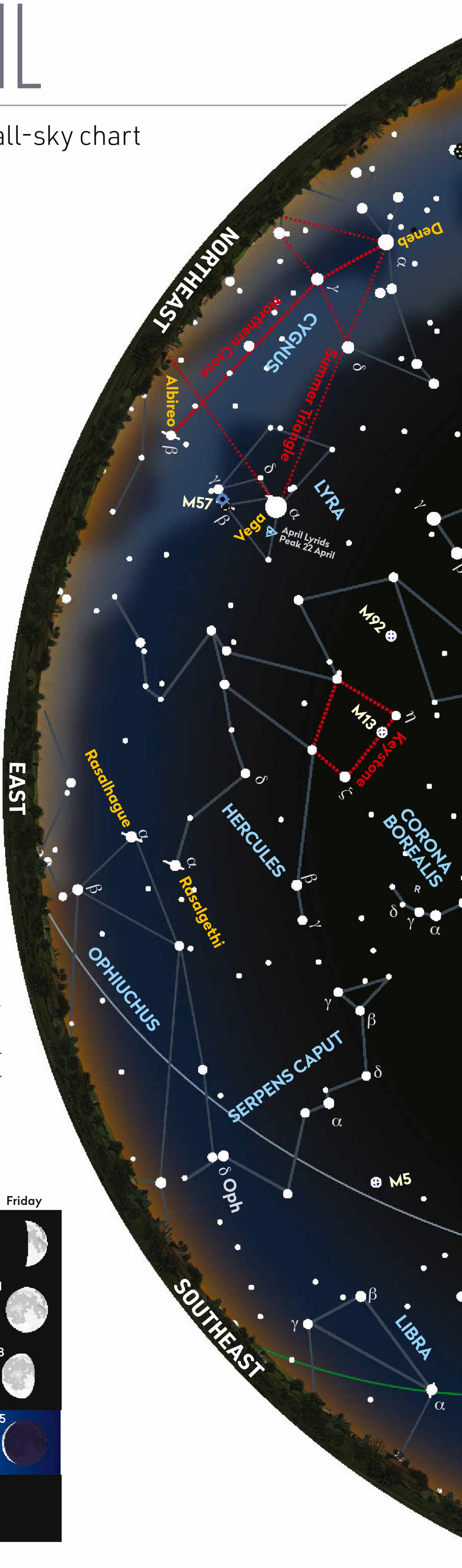
1 Apr 2025, 07:29 BST	17 Apr 2025, 00:56 BST
5 Apr 2025, 10:52 BST	21 Apr 2025, 04:01 BST
9 Apr 2025, 16:14 BST	25 Apr 2025, 04:53 BST
13 Apr 2025, 21:08 BST	29 Apr 2025, 05:53 BST

*Times correct for the centre of the UK

Lunar phases in April



Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
			1	2	3	4
5	6	7	8	9	10	11
12	13 FULL MOON	14	15	16	17	18
19	20	21	22	23	24	25
26	27 NEW MOON	28	29	30		

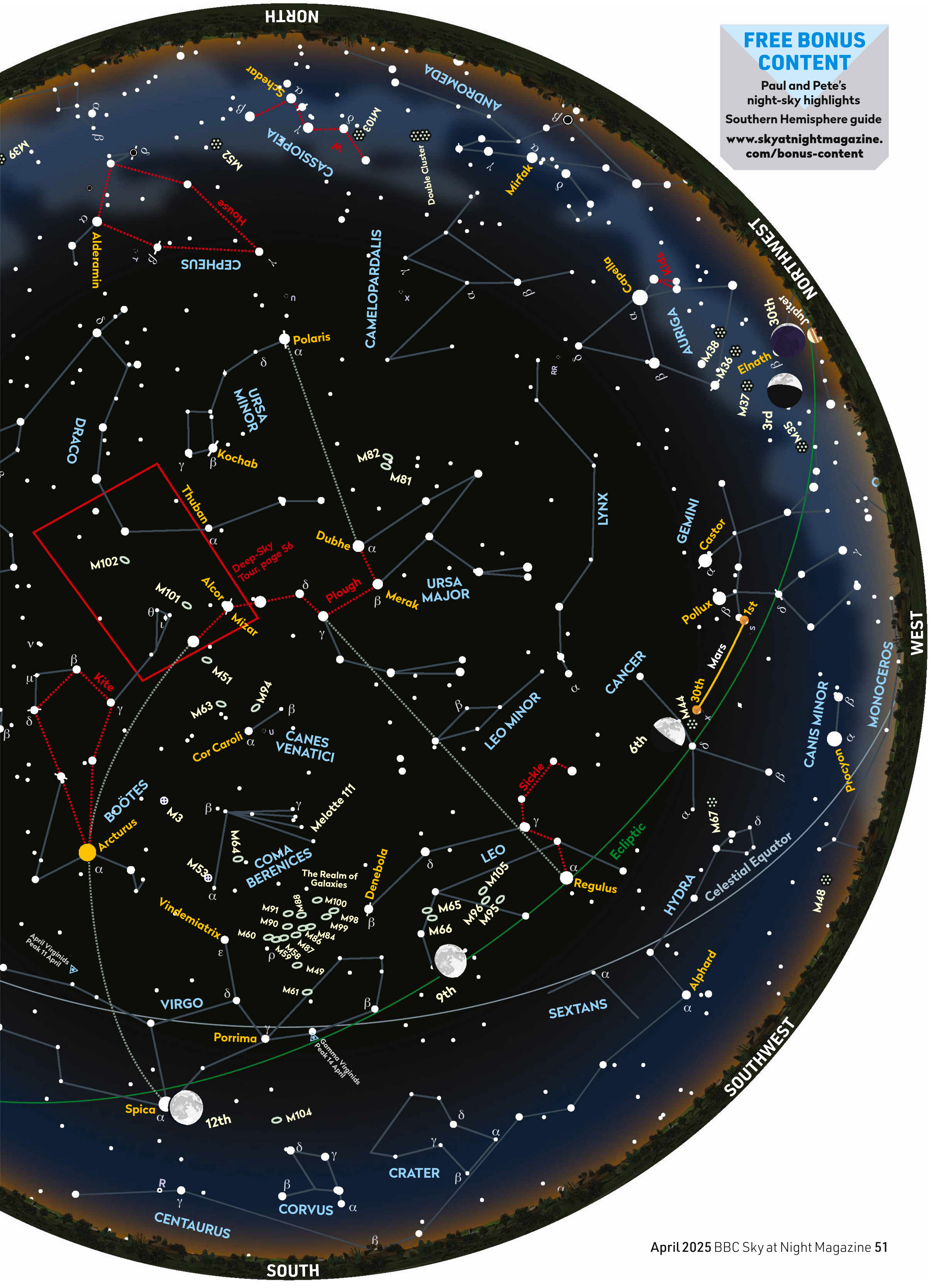

NORTHEAST
Deneb
α
γ
Northern Cross
CYGNUS
δ
Summer Triangle
Albireo
β
M57
γ
β
δ
Vega
α
LYRA
April Lyrids
Peak 22 April
γ
M92
EAST
M13
η
Keystone
ζ
Rasalhague
α
HERCULES
δ
β
CORONA BOREALIS
R
δ
γ
α
γ
β
α
Rasalgethi
OPHIUCHUS
γ
β
SERPENS CAPUT
δ
α
δ Oph
M5
SOUTHEAST
β
γ
LIBRA
α

FREE BONUS CONTENT

Paul and Pete's night-sky highlights

Southern Hemisphere guide

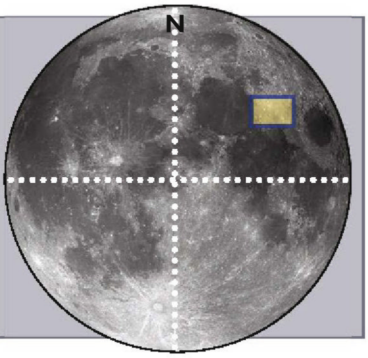
www.skyatnightmagazine.com/bonus-content


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
M39
Schedar
CASSIOPEIA
W
M103
M52
ANDROMEDA
Double Cluster
Mirfak
House
Alderamin
CEPHEUS
CAMELOPARDALIS
Kids
Capella
AURIGA
Jupiter
30th
M38
M36
Elnath
M37
3rd
M35
Polaris
URSA MINOR
Kochab
DRACO
RR
M82
M81
Thuban
LYNX
GEMINI
Castor
Dubhe
Deep-Sky Tour, page 56
M102
M101
Alcor
Mizar
Plough
Merak
URSA MAJOR
Pollux
1st
Mars
30th
M44
CANCER
6th
Kite
M51
M63
M94
Cor Caroli
CANES VENATICI
LEO MINOR
CANIS MINOR
MONOCEROS
Procyon
Sickle
BOÖTES
M3
Arcturus
Melotte 111
M64
M53
COMA BERENICES
The Realm of Galaxies
Denebola
LEO
M105
Regulus
Ecliptic
M67
HYDRA
Celestial Equator
Vindemiatrix
M91
M88
M100
M90
M98
M99
M84
M86
M60
M87
M58
M59
M49
M65
M96
M95
M66
9th
April Virginids Peak 11 April
M61
VIRGO
Alphard
SEXTANS
M48
Porrima
Gamma Virginids Peak 14 April
Spica
12th
M104
CRATER
CORVUS
CENTAURUS

MOONWATCH April's top lunar feature to observe

Römer

Type: Crater
Size: 40km
Longitude/latitude: 36.4° E, 25.4° N
Age: Around 3.9 billion years
Best time to see: Four days after first quarter (2 April) or three days after last quarter (16–17 April)
Minimum equipment: 50mm telescope



The crater **Römer** is named after Ole Rømer, the Danish astronomer who made the first measurements of the speed of light in 1676. It's a distinctive 40km-diameter crater somewhat disguised by its heavily cratered surroundings, located in the highland region to the east of 650km **Mare Serenitatis**. It sits in a position roughly one-quarter of the way from the eastern edge of Serenitatis, marked by the circular bay formed by the flooded 61km crater **Le Monnier** and the northwestern edge of 620km x 570km **Mare Crisium**. The surrounding region is rough and pockmarked by other craters, those to the south flooded by lava intrusions from 700km **Mare Tranquillitatis** to the south.

> *Steep cliffs delineate the entire edge of the crater, leading to a series of terraced ledges below*

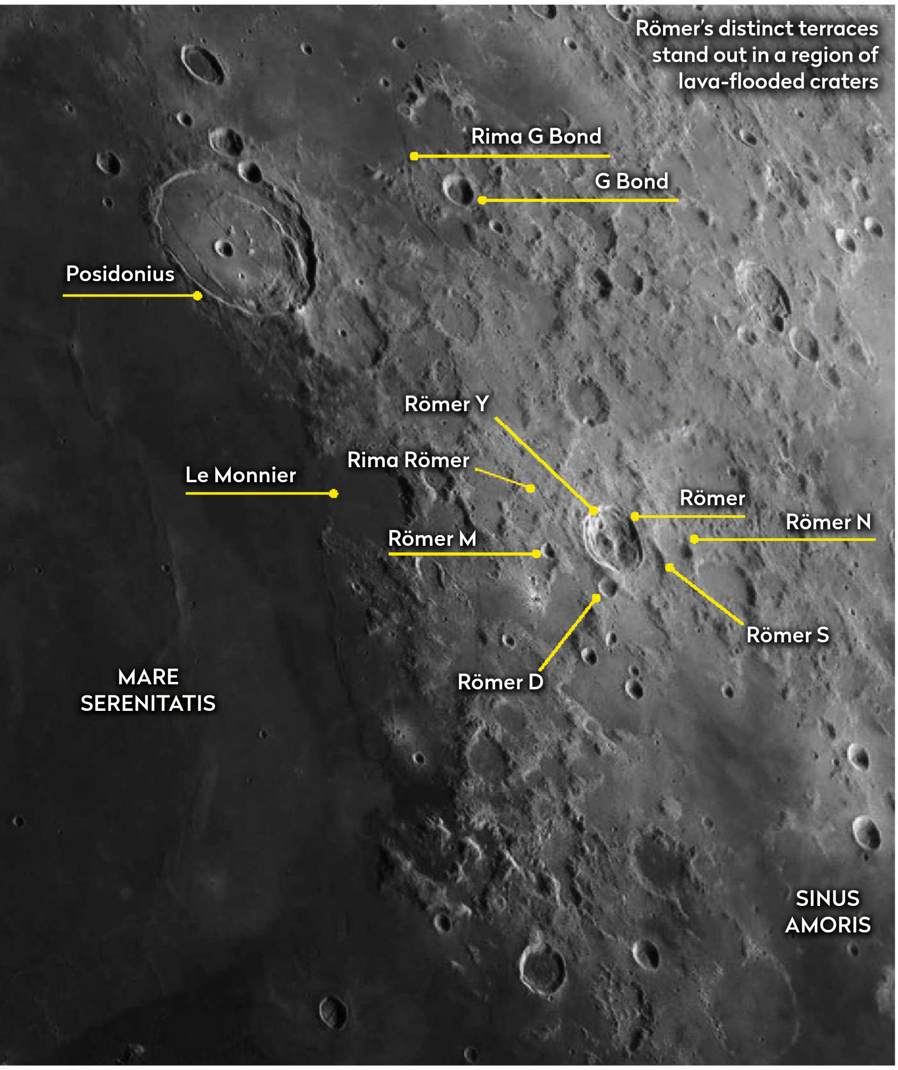
PETE LAWRENCE X 3

The lava interface between Serenitatis and Tranquillitatis is very noticeable, an almost linear dividing line of lighter tone on the Serenitatis side and darker Tranquillitatis lava to the south. A rough highland region lies to the east of this line with a flat lava extension north from Tranquillitatis to the east of these highlands. This is 250km x 150km **Sinus Amoris**, the Bay of Love. Römer sits at the northern end of this bay.

Römer stands out due to its sharp upper rim edge. Steep cliffs delineate the entire edge of the crater, leading to a series of terraced ledges below. The crater's floor is hard to determine, lost in rugged terrain, but there is a distinctive central mountain peak roughly 13km in diameter and around 1.2km in height. Overall, from the highest point on the rim to the lowest internal surface, is about 4km. North of the central peak sits the distinctive 6km craterlet **Römer Y**, the only identifiable craterlet within the main crater rim area.

Outside of Römer, there's a mishmash of forms consisting of rough highlands, flooded lava-filled craters and smaller craterlets. The closest distinct satellite crater lies just southwest of Römer in the form of 12.1km **Römer D**. But is it the closest? Look carefully at Römer and you can see that there's a similar-sized feature offset 20km to the south. It's old, battered and mostly overlaid by Römer, but under oblique lighting 43km **Römer S** is quite obvious. Immediately east of Römer S is the equally battered form of 25.5km **Römer N**.

Look 47km to the west of Römer's centre and you'll arrive at 9km **Römer M**. If you have access to a larger telescope, see if you can spot the tiny 3.5km craterlet that lies on its northern edge, creating the impression of a small notch. Between the western rim edge of Römer and Römer M runs a linear rille, more obvious to the north when lighting is oblique. This is 100km long and 4km wide **Rima Römer**, a feature that requires a 200mm or larger telescope to see properly. See how far north you can trace the rille. Eventually, it joins another more distinctive rille known as **Rima G Bond**. This example runs for 150km but is slightly narrower at 3km. Despite this, its path takes it across flat lava plains and this helps its visibility considerably. **G Bond** is the distinct 32km crater located 215km north of Römer.


Römer's distinct terraces stand out in a region of lava-flooded craters

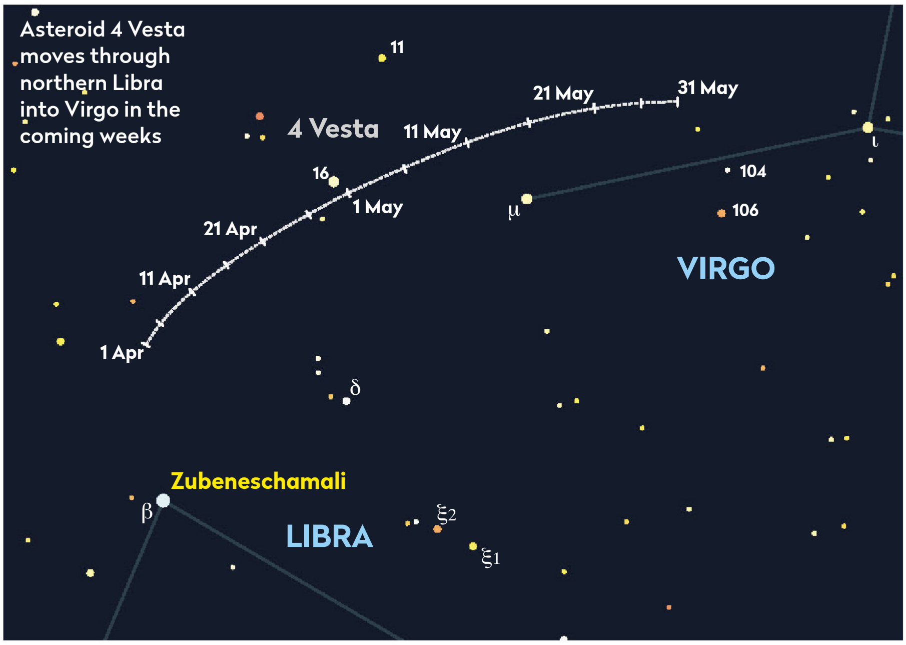
COMETS AND ASTEROIDS

Grab your binos to track brightening asteroid Vesta

Asteroid 4 Vesta reaches opposition on 2 May, when it can be found shining among the stars of northern Libra, close to the constellation's boundary with Virgo. At opposition, it's predicted to reach mag. +5.7, which places it within naked-eye territory from a dark-sky site, although binoculars are a better way to catch it.

On 1 April, mag. +6.6 Vesta sits 3° north of mag. +2.6 Zubeneschamali (Beta (β) Librae), thereafter proceeding to the west-northwest towards the mag. +4.5 star 16 Librae at the start of May. Its path arcs slightly north as it goes, taking it through a fairly barren part of the spring sky.

Discovered on 29 March 1807, Vesta was the fourth asteroid identified – hence its prefix '4'. It's the second most massive and second-largest body in the asteroid belt, only surpassed by dwarf planet Ceres, the first asteroid discovered. 1 Ceres was subsequently reclassified as a dwarf planet by the International Astronomical Union (IAU) in 2006, thereafter making Vesta the largest asteroid.


Asteroid 4 Vesta moves through northern Libra into Virgo in the coming weeks

Vesta takes 3.63 years to orbit the Sun and at favourable oppositions can be seen with the naked eye. Its opposition brightness varies between mag. +5.1 and mag. +8.5. It has been measured as 572.6km x 557.2km x 446.4km, which gives a mean diameter of 525.4km. Turn to page 55 for more on recording Vesta's visit.

STAR OF THE MONTH

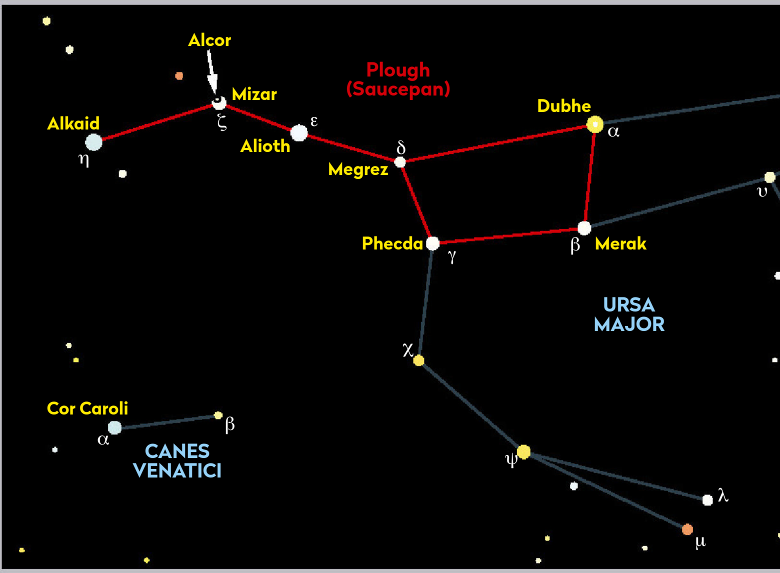
Alioth – a yo-yo star, chemically speaking

Alioth (Epsilon (ε) Ursae Majoris) is easy to locate as it's one of the seven stars that form the famous Plough or Saucepan asterism. Imagining the pattern as a saucepan, mag. +1.8 Alioth is the first star in the handle away from the edge of the pan. Although in one of the more minor positions in the pattern, it may come as a surprise that Alioth is actually the brightest star in the Saucepan, albeit only beating Dubhe (Alpha (α) Ursae Majoris) by 0.3 magnitudes. 'Alioth' translates as 'the sheep's fat tail'.

Alioth has a spectral type of A1III-IVp kB9, a long string of characters that needs some explanation. The 'A1' part indicates that it's a star that appears white in colour. The 'III–IV' indicates that it's regarded as being on the normal giant–subgiant border. The 'p' indicates it has a peculiar spectrum, while 'kB9' indicates that the star's spectrum includes the calcium-K line, representative of a B9-class star despite Alioth being an A1-type star.

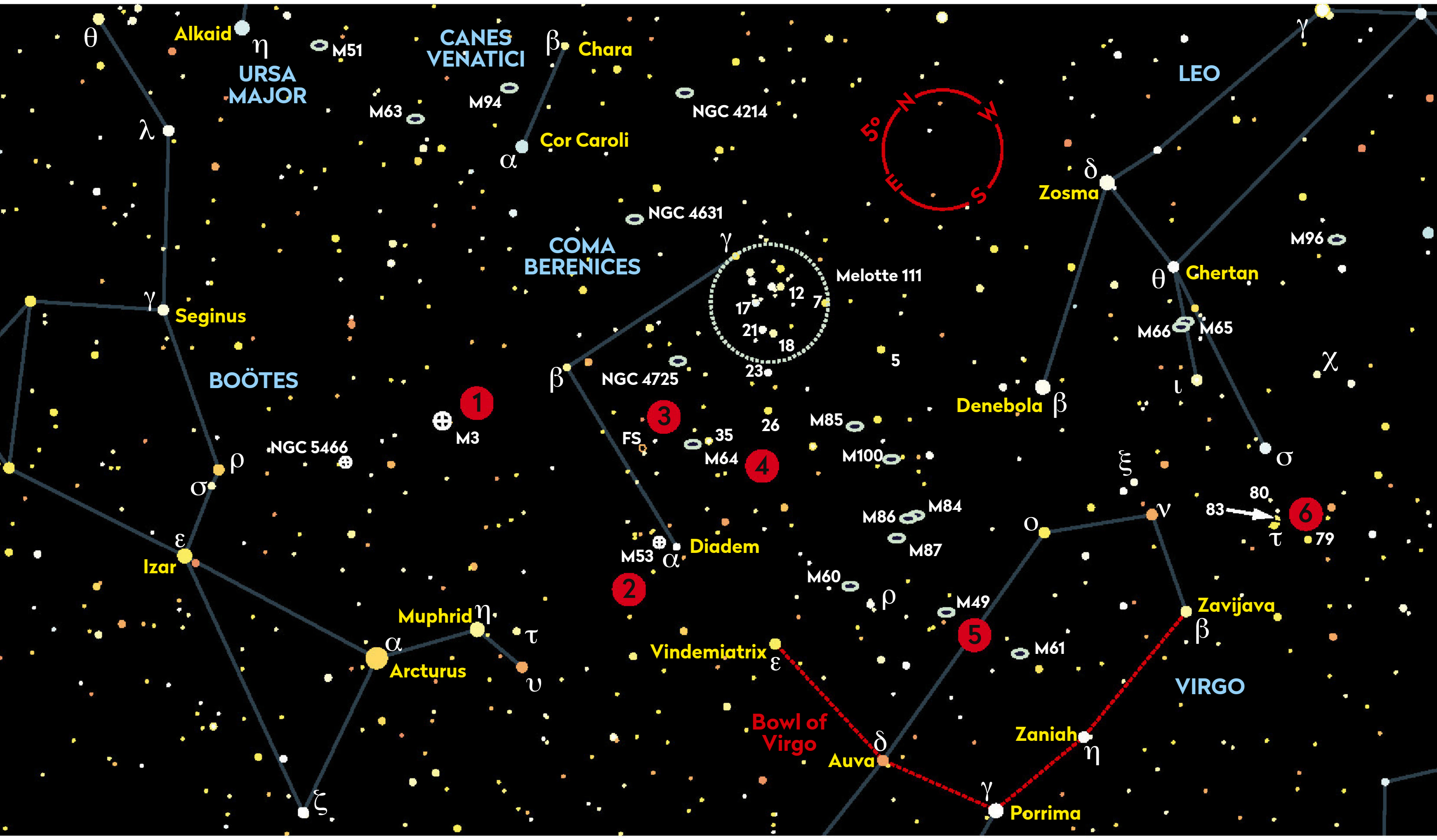
Alioth is classed as an Alpha^2 (α^2) Canum Venaticorum-type variable with spectral lines that vary over a period of 5.1 days. The variation may in part be due to a very strong magnetic field and an offset between the star's magnetic field axis and its rotational axis, separating different elements into bands which then appear to cross our line of sight to create the observed variability. The offset between Alioth's magnetic and rotational poles is believed to be around 90°.

▼ Alioth, on the handle of the Plough, exhibits unusual spectroscopic changes



BINOCULAR TOUR With Steve Tonkin

Split some tricky doubles, find two brilliant balls of stars and give yourself a black eye


θ
Alkaid
η
M51
URSA MAJOR
CANES VENATICI
β
Chara
M63
M94
NGC 4214
Cor Caroli
α
λ
LEO
γ
5°
N
W
E
S
δ
Zosma
NGC 4631
COMA BERENICES
γ
Melotte 111
12
17
7
21
18
23
M96
θ
Chertan
M66
M65
γ
Seginus
BOÖTES
β
NGC 4725
1
M3
3
5
Denebola
β
χ
ι
FS
35
26
M85
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NGC 5466
σ
M64
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M100
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Izar
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Diadem
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M60
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M49
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Muphrid
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Vindemiatrix
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M61
VIRGO
Bowl of Virgo
δ
Auva
Zaniah
η
γ
Porrima
ζ

1. M3

10x50 We'll start the tour with one of the best globular clusters in the northern sky. There are no nearby bright stars to help you find it. However, if you look mid-way between Arcturus (Alpha (α) Boötis) and mag. + 2.9 Cor Caroli (Alpha (α) Canem Venaticorum), you should find what looks like a badly focused star. This is the glow of the nearly half-million stars of globular cluster M3. ☐ **SEEN IT**

2. M53

10x50 Our next globular cluster lies 1° north-east of mag. +4.4 Diadem (Alpha (α) Comae Berenices). This tiny misty patch will appear to grow in size, fuzziness and brightness if you centre it in the field of view and then avert your gaze back to Diadem. This is M53, and the apparent changes you just witnessed show the difference between direct and averted vision. You'll find this technique useful when we look at galaxies later in the tour. ☐ **SEEN IT**

3. FS Comae Berenices

10x50 Go to a point mid-way between Diadem and mag. +4.2 Beta (β) Comae Berenices, then look 1° to the west, where you'll find an orange star, FS Comae Berenices, shining somewhere around mag. +6. The magnitude of this semi-regular variable star fluctuates between +6.1 and +5.3, with a period of 55–58 days. The star's spectrum shows varying Doppler shifts, suggesting that its variability is due to pulsations in size. ☐ **SEEN IT**

4. The Black Eye Galaxy

15x70 Its high surface brightness means that under dark, transparent skies it's fairly easy to see mag. +8.5 galaxy M64. Find this elongated oval glow 1° east-northeast of mag. +5.0 35 Comae Berenices. With averted vision, its long axis appears about a quarter of the apparent diameter of the Moon, but you won't see the dark dust lane that gives it its common name, the Black Eye Galaxy. ☐ **SEEN IT**

5. M49

15x70 Find Rho (ρ) Virginis and place it on the north-east of your field of view. On the opposite side, you should find a small, slightly oval patch of light between a pair of sixth-magnitude stars, just over a degree apart and orientated southeast–northwest. This is the 37-million-year-old light of galaxy M49. Try averted vision again to see how many more galaxies you can detect in this region of sky. ☐ **SEEN IT**

6. Leo's Double Double

10x50 Use the chart to locate mag. +4.9 star Tau (τ) Leonis and its fainter companion, mag. +6.5 83 Leonis 20 arcminutes to the north-west. If you look carefully, you'll see each of these is itself a double star with a mag. +7.5 companion. Tau's pale companion is easier to discern at 1.5 arcminutes but, at only 29 arcseconds, splitting 83 Leo is a tough challenge for 10x50 binoculars. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

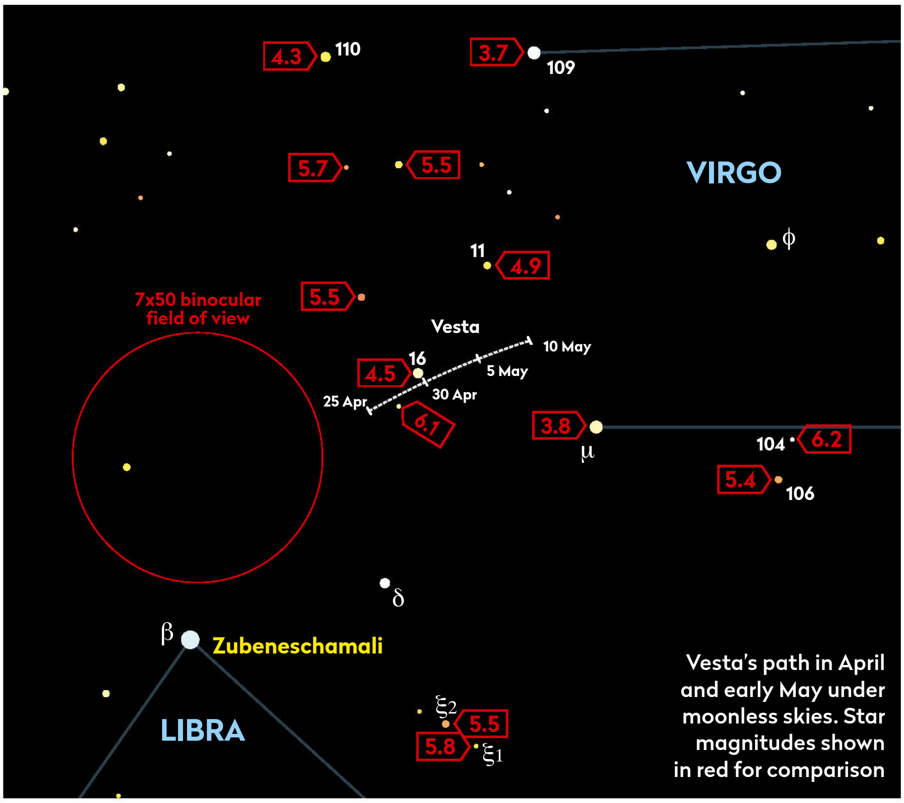
THE SKY GUIDE CHALLENGE

Get to know northern Virgo, then snap or sketch asteroid 4 Vesta when it drops by

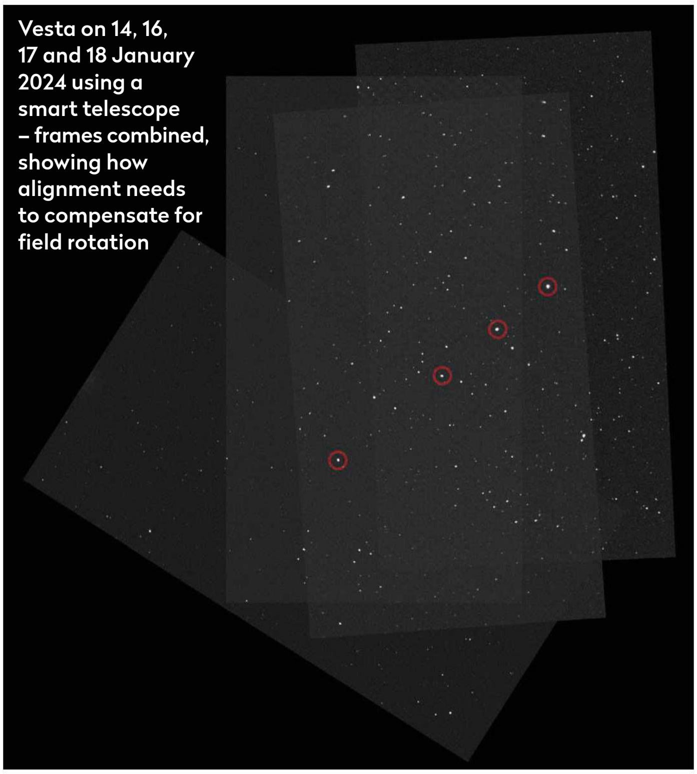
Minor planet 4 Vesta reaches opposition on 2 May, a time when, for the current period of visibility at least, the object is closest to Earth and at its brightest. As we approach opposition, towards the end of April is a great time to get acquainted with the patch of sky it's going to pass through. If you've never seen a minor planet before, you can prep for the task by photographing the area during April. Alternatively, go old school and, using binoculars or a small telescope on a low power, make a sketch of the stars in the area. Sketching the stars will really get you connected to this patch of sky.

The idea behind recording the star field early is that this will give you a reference frame to compare to images or sketches made when Vesta passes through, offering an easy way to identify the presence of the minor planet.

If you have access to a dark-sky site, another thing you can try is to record the area you can see with the naked eye during a clear, dark night in April. Obviously, you don't want any light pollution, either artificial or natural, so the periods 1–4 April and 18–30 April are recommended because there will be less interference from the Moon.



Vesta's path in April and early May under moonless skies. Star magnitudes shown in red for comparison



Vesta on 14, 16, 17 and 18 January 2024 using a smart telescope – frames combined, showing how alignment needs to compensate for field rotation

Make sure that your eyesight is properly dark-adapted, keeping your eyes in darkness for at least 20 minutes. Being relaxed and taking your time helps too, a reclining chair being a great way to achieve this state. Record as many stars as visible in the area.

See whether you can record it with just your eyes... it should just be possible

To sketch the area, you'll need to be able to see what you're recording the stars on; to retain your dark-adapted vision, we recommend using a really dim head torch or equivalent for this. Then, as Vesta passes through the field around opposition from 28 April through to 4 May, the Moon reappearing from 5 May onwards, make your attempt and see whether you can record it with just your eyes. Peak magnitude is predicted at +5.7, so it should just be possible. We'd recommend using the mag. +4.5 star 16 Librae as the navigational anchor for this attempt.

If you have a smart scope, imaging Vesta is a fairly trivial exercise. Search for the object in the control app and the scope will locate it and do all of the imaging for you. Try to collect as many images from separate nights as you can; these can be loaded into a layer-based editor as separate layers. Align the stars between layers, rotating if required to compensate for field rotation. Flicking between layers should clearly show how Vesta moves from one night to the next.

DEEP-SKY TOUR

Enjoy a hop around six beautiful spring galaxies in the region of southern Draco

1 NGC 6015

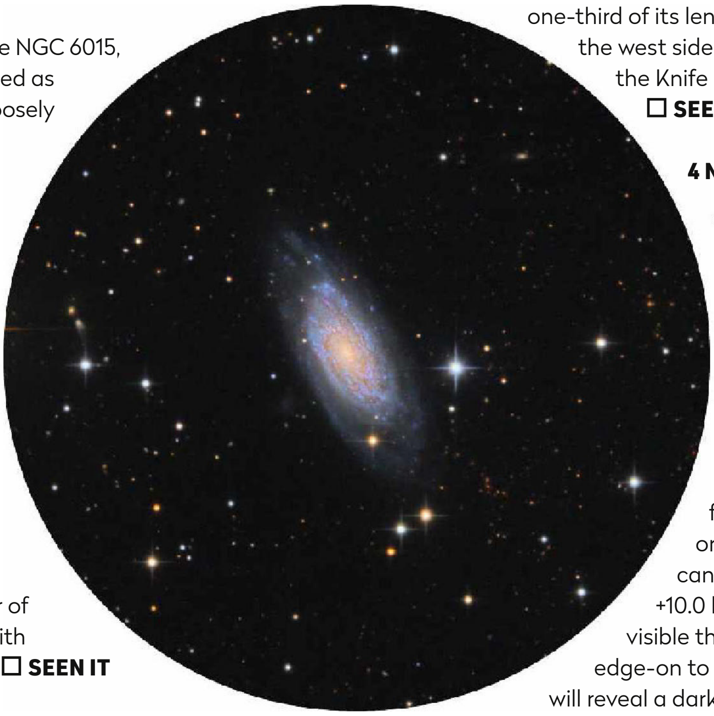
First is 11th-magnitude NGC 6015, a spiral galaxy classified as Sc-r: 'Sc' meaning its arms are loosely wound and 'r' indicating it has a ring-like structure. A 150mm scope barely shows it, better revealing the foreground mag. +11.4 star near the galaxy's core. A 250mm scope shows it as a broad 3.0 x 1.3-arcminute ellipse, brighter towards the core. With a 300mm scope, you'll see a 6.0 x 2.0-arcminute ellipse with hints of a ringed structure. At 40 million lightyears away, NGC 6015 is 4.6° northeast of mag. +3.3 Edasich (Iota (ι) Draconis). It also marks the northwest corner of an equilateral triangle formed with Edasich and Theta (θ) Draconis. ☐ **SEEN IT**

2 NGC 5985

From Edasich, slew 1.9° east and a fraction north to mag. +11.0 spiral galaxy NGC 5985. This type SAB(r)b spiral is similar to NGC 6015, but it's the field that's interesting. Head 7.7 arcminutes west of NGC 5985 to NGC 5982, a type E3 elliptical. Its surface brightness is higher than NGC 5985 but there's less structure save for a bright inner core half the galaxy's full size. Then 6.3 arcminutes west of NGC 5982 is NGC 5981, a 13th-magnitude Bbc-type edge-on spiral resembling a needle of light. All three are visible in a 150mm scope, forming the Draco Triplet. NGC 5985, 5982 and 5981 are 140, 130 and 112 million lightyears away, respectively. ☐ **SEEN IT**

3 NGC 5907

Travel back to Edasich and from there head 2.9° south-southwest to locate NGC 5907 which, like NGC 5981, is a rather splendid edge-on spiral. A 150mm scope shows the galaxy as a 6-arcminute scratch of light. Larger instruments max out the apparent length of the object at around 9 arcminutes, its width remaining tantalisingly thin at 0.8 arcminutes; that's similar to the apparent diameter of Jupiter. Through a 300mm or larger scope, this 47 million lightyears' distant galaxy has a faint dust lane that appears to run for around one-third of its length, adjacent to the core on the west side. NGC 5907 is also known as the Knife Edge Galaxy or Splinter Galaxy. ☐ **SEEN IT**



▲ The first stop-off on our tour is the delightful spiral galaxy NGC 6015. With larger instruments you'll be able to discern its ringed structure

GÜNTER KERSCHHUBER/CCDGUIDE.COM

4 NGC 5866

We continue the edge-on theme with the somewhat controversial galaxy NGC 5866, 1.4° west-southwest of NGC 5907. The controversy relates to the Messier catalogue, where NGC 5866 is often identified as M102; but it has also been claimed that Messier's entry for M102 is a duplicate of M101 or one of several other nearby candidates. NGC 5866 is a mag. +10.0 lenticular (SA0) galaxy, easily visible through a 150mm scope. It's edge-on to us and long-exposure photos will reveal a dark dust lane splitting the galaxy down its long axis, an unusual feature for a lenticular. A large scope shows it as a 3 x 1-arcminute streak. Known as the Spindle Galaxy, NGC 5866 is 50 million lightyears away. ☐ **SEEN IT**

5 NGC 5585

You'll need to head 6.6° west and 1.0° north from NGC 5866 to reach our next target, NGC 5585, just across the border in Ursa Major. This is a SAB(s)d-type spiral galaxy located between 18.6 and 28 million lightyears away. It shines with an integrated magnitude of +10.9 and is part of what's known as the M101 Group, named after the brightest galaxy in this loose association, M101, the Pinwheel Galaxy. NGC 5585 is quite a challenging target, barely visible as a 1-arcminute glow in a 150mm scope. It appears elongated and bigger through larger apertures, but the only structure is a weak brightening towards its core. ☐ **SEEN IT**

6 M101

We've mentioned M101 several times on this tour, so it seems fitting to finish off with this large, bright, face-on SAB(rs)cd-type spiral galaxy in Ursa Major. It's 3.3° southwest of NGC 5585; imagine the eastern corner of a slightly squat, almost equatorial triangle formed with Mizar (Zeta (ζ) Ursae Majoris) and Alkaid (Eta (η) Ursae Majoris) as the base. Located 21 million lightyears away, M101 is easily visible as a large object 20 x 15 arcminutes across in a 150mm scope. The central core brightens towards a star-like nucleus. Larger apertures reveal a mottled texture in the core, as well as beautiful and delicate structures in the extensive spiral arms. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can take you to this month's targets at the touch of a button. Find the Deep-Sky Tour file in our free Bonus Content online.

FREE BONUS CONTENT

Print this chart and take the Go-To tour
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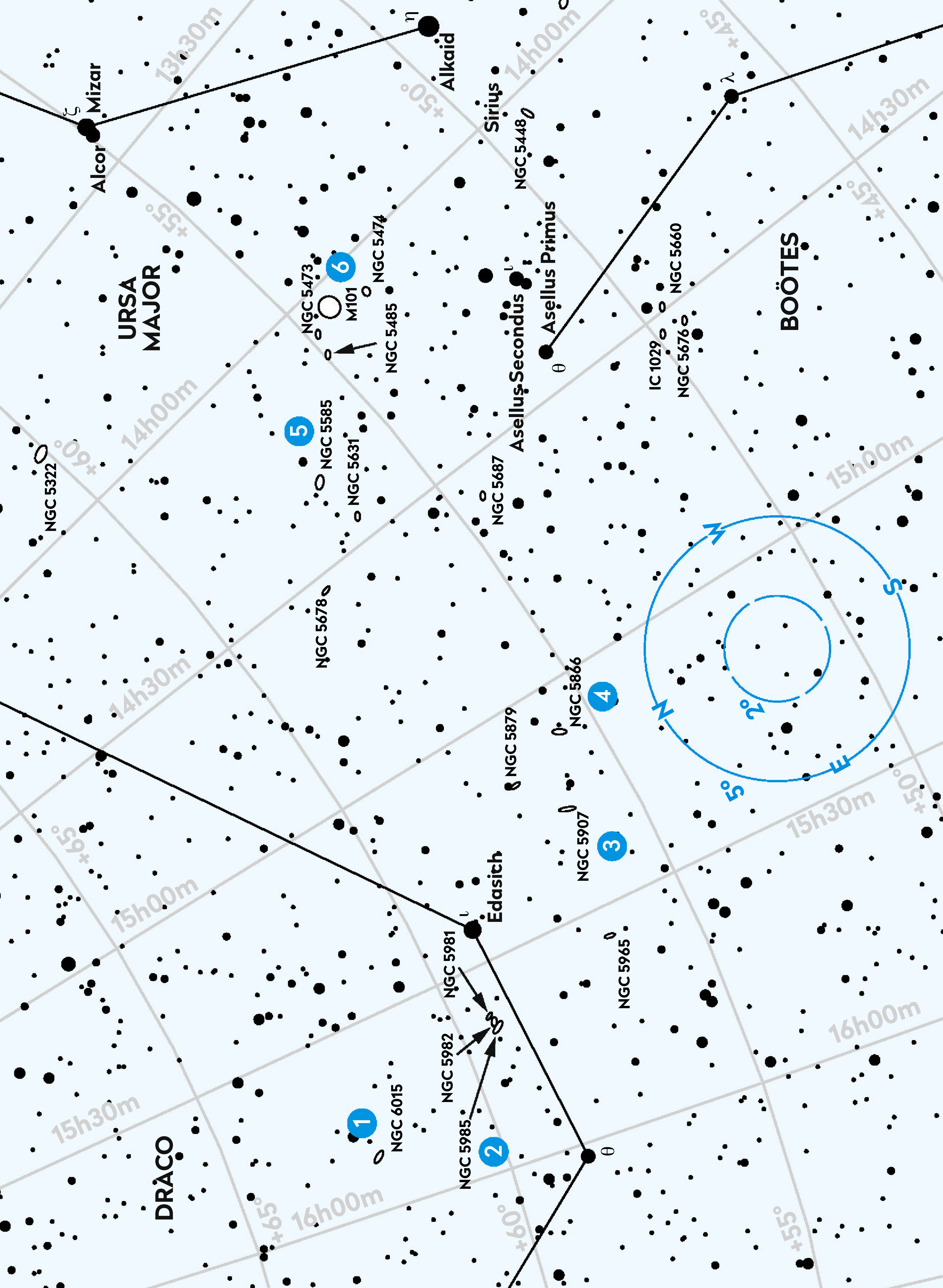

URSA MAJOR
BOÖTES
DRACO
Mizar
ζ
Alcor
η
Alkaid
Sirius
NGC 5448
λ
Asellus Primus
ι
Asellus Secondus
θ
NGC 5473
6
NGC 5474
M101
NGC 5485
NGC 5660
IC 1029
NGC 5676
5
NGC 5585
NGC 5631
NGC 5322
NGC 5687
NGC 5678
NGC 5866
4
NGC 5879
NGC 5907
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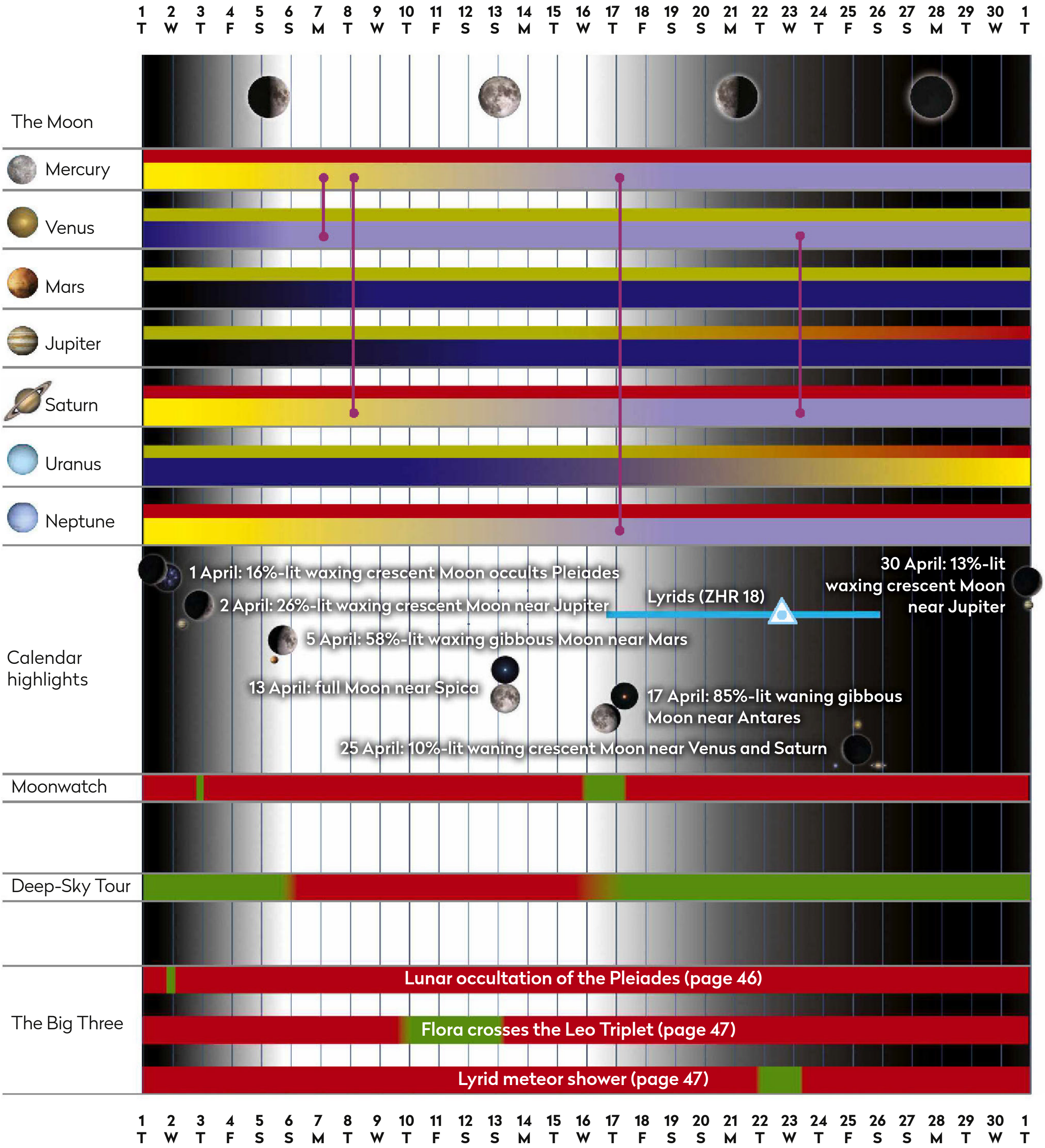
Edasich
NGC 5981
NGC 5982
NGC 5985
2
1
NGC 6015
NGC 5965
θ
N
S
E
W
2°
5°
13h30m
14h00m
14h30m
15h00m
15h30m
16h00m
+45°
+50°
+55°
+60°
+65°

AT A GLANCE

How the Sky Guide events will appear in April



1 April: 16%-lit waxing crescent Moon occults Pleiades

2 April: 26%-lit waxing crescent Moon near Jupiter

5 April: 58%-lit waxing gibbous Moon near Mars

13 April: full Moon near Spica

17 April: 85%-lit waning gibbous Moon near Antares

25 April: 10%-lit waning crescent Moon near Venus and Saturn

30 April: 13%-lit waxing crescent Moon near Jupiter

Lunar occultation of the Pleiades (page 46)

Flora crosses the Leo Triplet (page 47)

Lyrid meteor shower (page 47)

KEY

Observability

🟩 Optimal
🟥 Poor

Best viewed

Morning twilight
Daytime
Evening twilight
Night

Sky brightness during lunar phases

Dark (first quarter)
Light (full Moon)
Dark (last quarter)
Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)
SC Superior conjunction
OP Planet at opposition
△ Meteor radiant peak
Planets in conjunction

Full Moon
First quarter
Last quarter
New Moon

CHART BY PETE LAWRENCE

R910X RECYCLED HOODED PADDED PARKA

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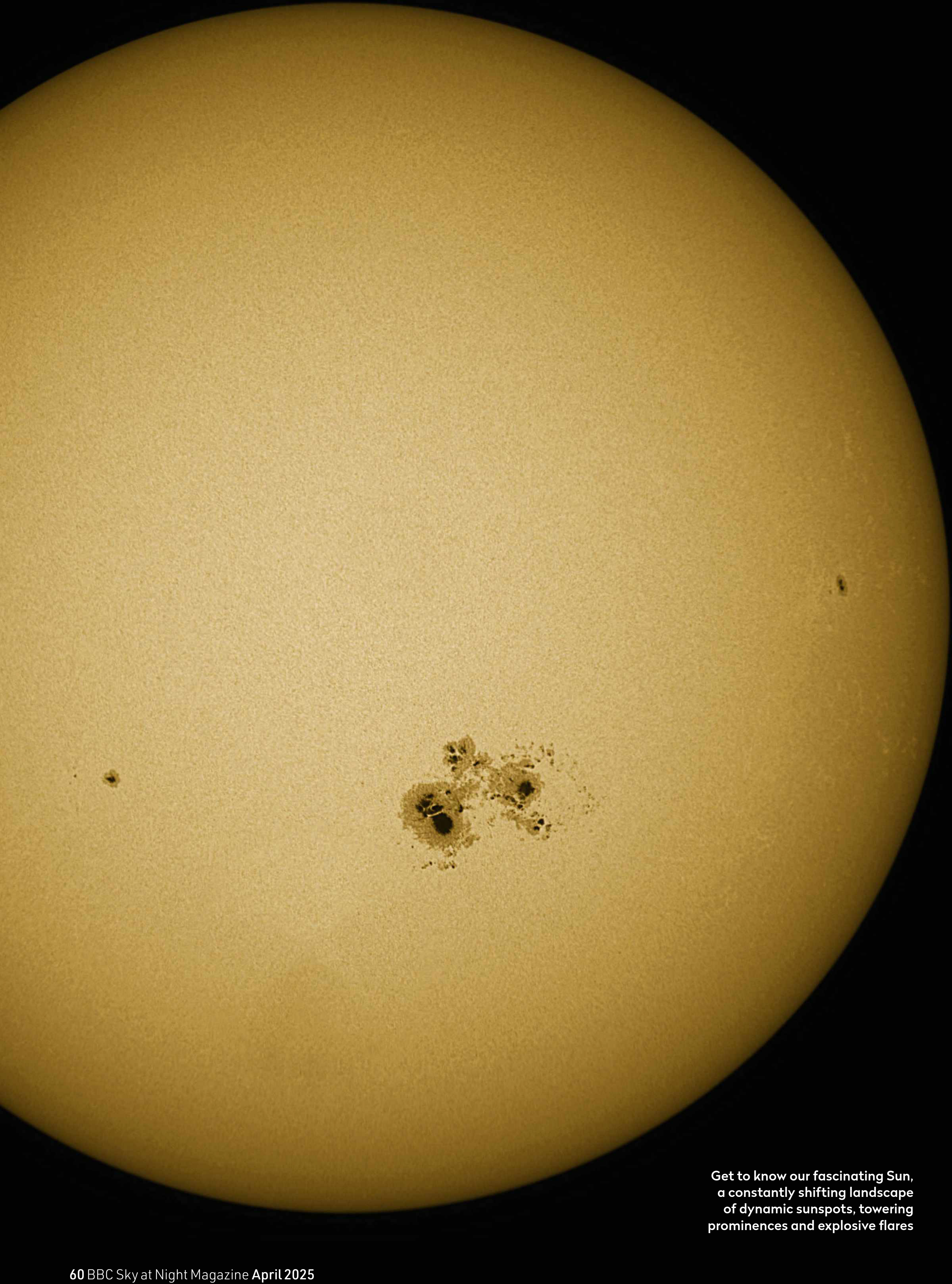


Get to know our fascinating Sun, a constantly shifting landscape of dynamic sunspots, towering prominences and explosive flares

CAUTION
Don't look at the Sun directly with the naked eye or any unfiltered optical instruments

As long as you take the right precautions, observing the Sun is a thrilling hobby anyone can enjoy

Catch the Sun

A complete guide to safe solar observing

Want to see a star up close? Solar expert **Stephen W Ramsden** reveals the different ways to see our Sun in incredible detail

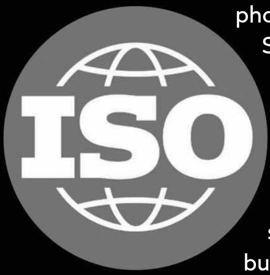
On Christmas Day 1977, 12-year-old me set up the 4-inch cardboard-tubed reflector that Santa had delivered to my house and screwed the little solar filter on to the supplied eyepiece. I immediately aimed it at the Sun and couldn't believe how amazingly beautiful it was. The rest is history – I've been chasing the Sun through our skies ever since. And right now, there's never been a better time to get involved with solar observing.

Our Sun has hit 'solar maximum'. This is the time in its 11-year cycle when solar magnetic fields are at maximum disarray, causing massive solar flare explosions, giant sunspots, tremendously powerful active regions, erupting prominences, coronal mass ejections and all sorts of ferocious plasma activity. The hobby of solar astronomy has finally reached its apex as well, with several manufacturers now offering safe and easy-to-use telescopes and spectrographs that allow even complete beginners to watch and image some of the most breathtaking astronomical phenomena in our Universe.

Protect your eyes

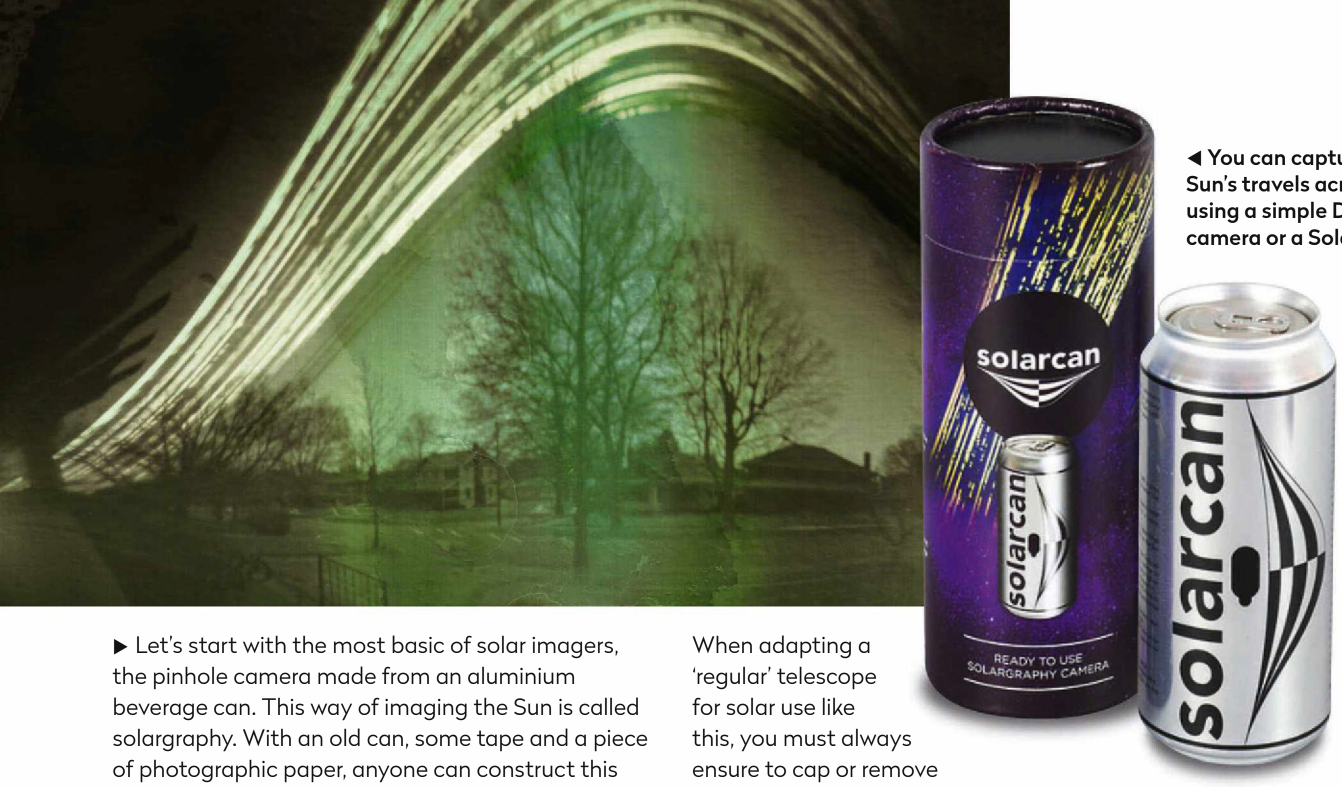
If you've been looking for a new hobby, we'll show you some of the best ways to get you and your family into what I believe is the greatest hobby on Earth: solar astronomy.

First, a word on safety. Safe solar viewing requires more than just a dark piece of glass or similar to dim the image. The Sun radiates an enormous amount of near-ultraviolet and near-infrared light that can immediately and irrevocably damage the rod and cone photoreceptors of your eyes. Stick with authorised and safe solar-viewing equipment and look for the ISO seal on whatever you buy to view the Sun. Viewing the Sun through modern, certified solar astronomy gear is safe, but making your own without a complete understanding of the risks is not good. Be careful and do it right. ▶



Never take risks: only use ISO solar safety certified equipment

STEPHEN W. RAMSDEN, CAVAN IMAGES/ALAMY STOCK PHOTO, ISO



◀ You can capture the Sun's travels across the sky using a simple DIY pinhole camera or a Solarcam

▶ Let's start with the most basic of solar imagers, the pinhole camera made from an aluminium beverage can. This way of imaging the Sun is called solargraphy. With an old can, some tape and a piece of photographic paper, anyone can construct this imager that, when properly aligned with the horizon, will give you a six-month or a full-year exposure of the track that our Sun takes through the seasonal skies. There are several websites available that explain this simple process (*BBC Sky at Night Magazine*'s is available at bit.ly/pin-hole-cam) and it can all be done almost for free. You can also purchase a ready-made Solarcan solargraphy cameras.

Also basic to solar observing are the mylar filtered solar glasses you've seen people use to watch a solar eclipse. These can be reused indefinitely as long as they aren't scratched or damaged. Lunt Solar Systems and Celestron also sell solar binoculars (sunoculars) that have been specially modified for safe viewing of the Sun's photosphere. These items are portable, inexpensive and will open the door to the wonders of the Sun for you and your family.

Sunspots and faculae

Do you have a telescope at home that's gathering dust? Consider investing in a white-light solar filter that fits over the objective (front) end of the scope. When adapting a 'regular' telescope for solar use like this, you must always ensure to cap or remove any finderscope, cap the front lens when not in use and never leave the telescope unattended. This will give you wonderful views of the Sun's photosphere, allowing you to track surface features as they move across the Sun throughout its 24–27-day orbital period. White-light viewing is sort of astro street-slang for looking at all of the wavelengths of

LAURA LIM PRESCOTT/GETTY, SOLARCAN.CO.UK X 2, STEPHEN W. RAMSDEN X 3, BBC SKY AT NIGHT MAGAZINE, HELIOSTAR: WWW.FIRSTLIGHTOPTICS.COM, WHITE LIGHT FILTER: PETE LAWRENCE

Stephen Ramsden

◀ The author modelling eclipse glasses, a low-cost option that blocks out most of the harmful light

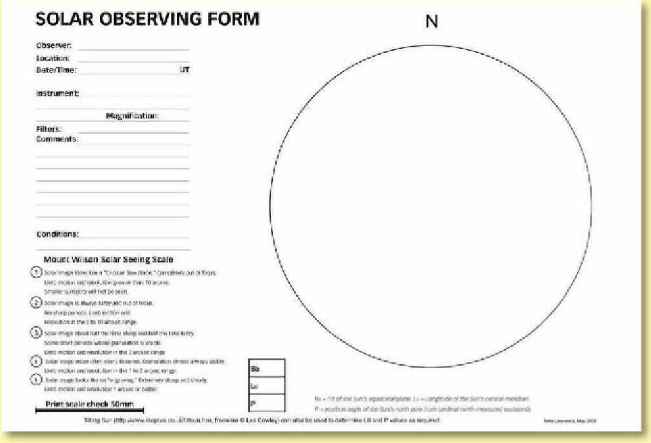
Become a solar scientist

Do you regularly observe the Sun? Your data could help solar science

Amateur astronomers can make a valuable contribution to solar science through their observations and images of the Sun. You may be a seasoned expert in solar photography or a complete beginner, but why not use your skills for citizen science?

Keep a logbook of your observations and any images or sketches you make. Make sure each record contains your name, the date, the location and the time in UT.

In the UK, the British Astronomical Association's Solar section welcomes amateur data, as does the American Association of Variable Star Observers (AAVSO). And data on sunspots specifically can be submitted to the Sunspot Index hosted by the Royal Observatory of Belgium.


SOLAR OBSERVING FORM

N

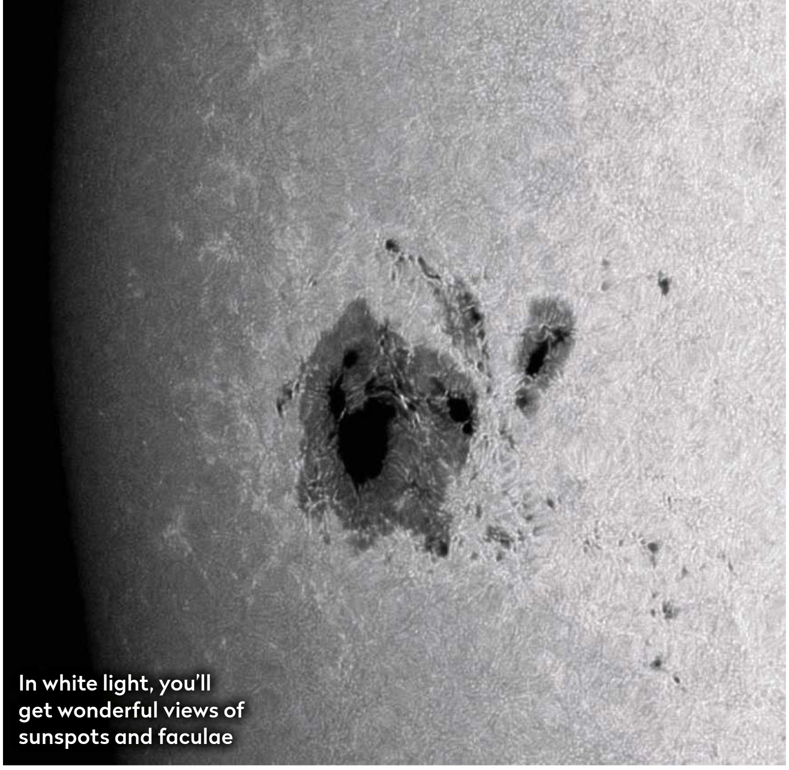
Observer:
Location:
Date/Time: UT
Instrument:
Magnification:
Filters:
Comments:
Conditions:

Mount Wilson Solar Seeing Scale

Print scale check 50mm

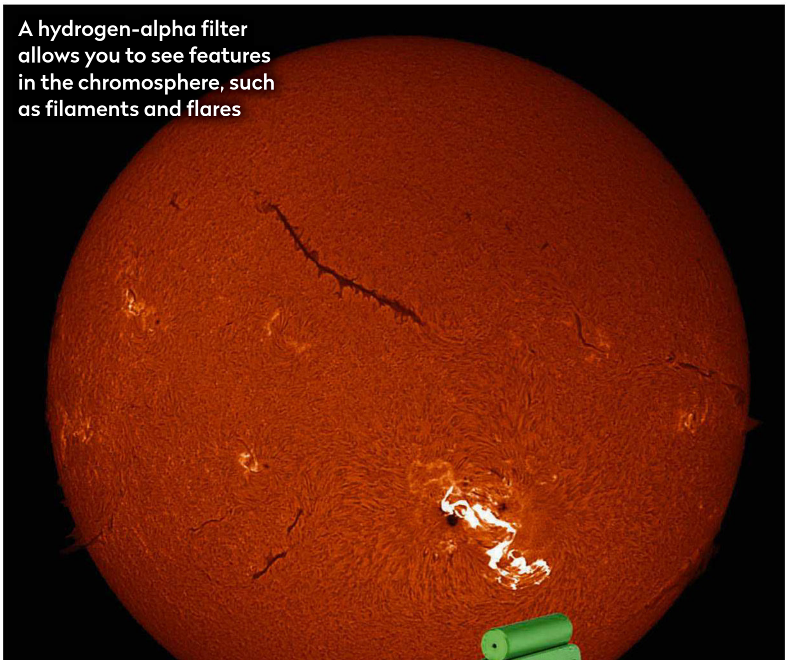
Bo
Lo
P

▲ Find a solar observing form in our Bonus Content – see page 5



In white light, you'll get wonderful views of sunspots and faculae

Fit a certified white-light filter onto the front of your scope to make it Sun-safe



A hydrogen-alpha filter allows you to see features in the chromosphere, such as filaments and flares

Sky-Watcher
HELIOSTAR 76Hα

▲ **Dedicated solar telescopes like the Heliostar H-alpha are becoming more affordable**

light in the solar spectrum combined. With this method, you'll see dark sunspots and brighter faculae, which are magnetically charged hot spots usually associated with active regions. White-light solar observing is a great way to breathe new life into your unused astronomy gear. Several manufacturers make reasonably priced objective filters, or turn to page 74 for a step-by-step guide to making a DIY version.

Solar astronomy done this way is a great chance to expose your kids to some really cool science and spark their interest in learning more.

For those that have a little experience already or want to jump right into the deep end of the solar pool, there is a fantastic choice of gear available for narrowband solar astronomy. Narrowband solar observing refers to viewing single wavelengths of light in the Sun's spectrum.

Prominences, flares and more

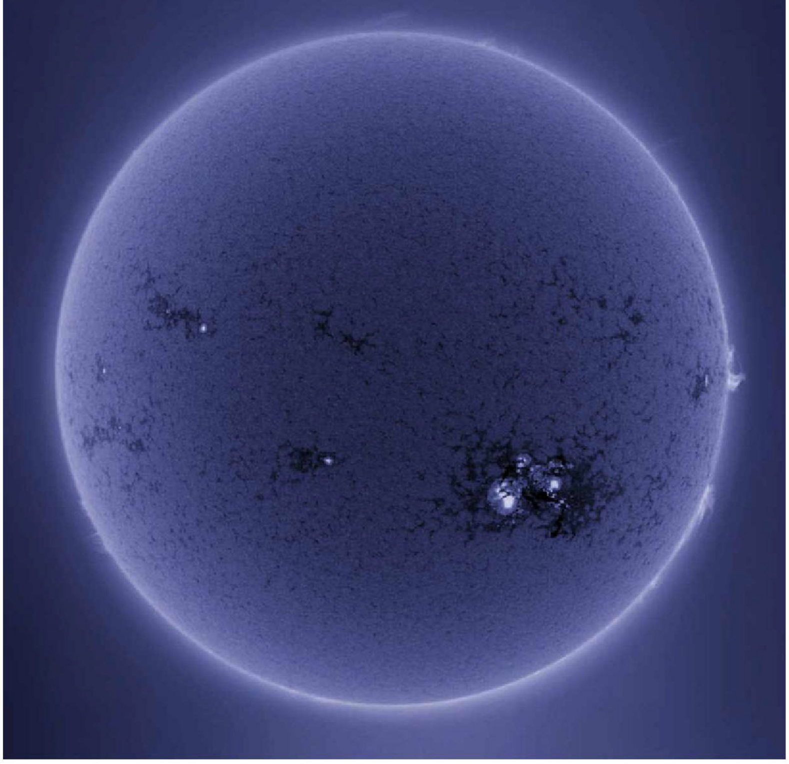
Modern narrowband solar gear is capable of discriminating passbands from emission lines in the Sun's continuum as small as 0.2 angstroms. An angstrom is 1/100,000,000th of a centimetre or 10^{-10} metres. That's really, really small! (A hydrogen atom is about 1 angstrom in diameter.)

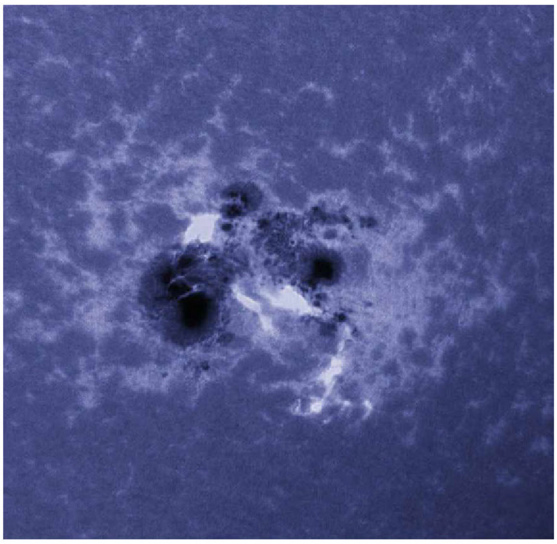
When viewing the Sun through narrowband filters, you'll be able to watch – or capture images or videos of – powerful flares erupting from the Sun's surface. You'll also see meandering, gigantic plasma structures called filaments, and prominences held aloft by magnetic field lines. Watching these drift across the Sun right before your eyes is an incredible experience.

Dedicated hydrogen-alpha solar telescopes show the Sun's chromosphere, which is the layer of atmosphere between the surface and the corona. They're called hydrogen-alpha, or H-alpha, telescopes because they're designed to safely show the first (alpha) emission line from the hydrogen atom in the Balmer series of emission lines in the Sun's spectrum (this may sound like gobbledygook to most, but the science of light and how it's produced and disseminated from the Sun is one of the most remarkable things you can study in our natural world).

While they're still a serious investment, H-alpha scopes such as Sky-Watcher's Heliostar are becoming more affordable. What used to cost £8,000 ($10,000) 20 years ago can now be had for £2,400 ($3,000) or less from today's manufacturers. The Heliostar uses a single etalon filter to achieve what took multiple filters in the past. Other instruments worth investigating include Lunt's 50mm H-alpha solar telescope and DayStar's Quark H-alpha eyepiece.

The less visible, but easily imaged, near-ultraviolet end of the spectrum may be explored using a ▶





▲ **For a different and spectacular perspective, a calcium-K filter reveals even greater detail**

▶ widely available calcium-K filter. These devices are inserted into your refracting telescope to reveal the upper chromosphere, where calcium atoms are ionised by the Sun's energy, releasing photons with an eery purplish glow.

Latest home solar tech

Perhaps the most exciting thing in solar astronomy currently, for those that want the most detailed views possible, combined with usable scientific data, would be the spectroheliograph from MLAstro in Vietnam. This technology is very old, but up until pioneers like Christian Buil and software author Cédric Champeau made a 3D-printable device and the means to process the data a reality, it was limited to high-end university and research observatories.

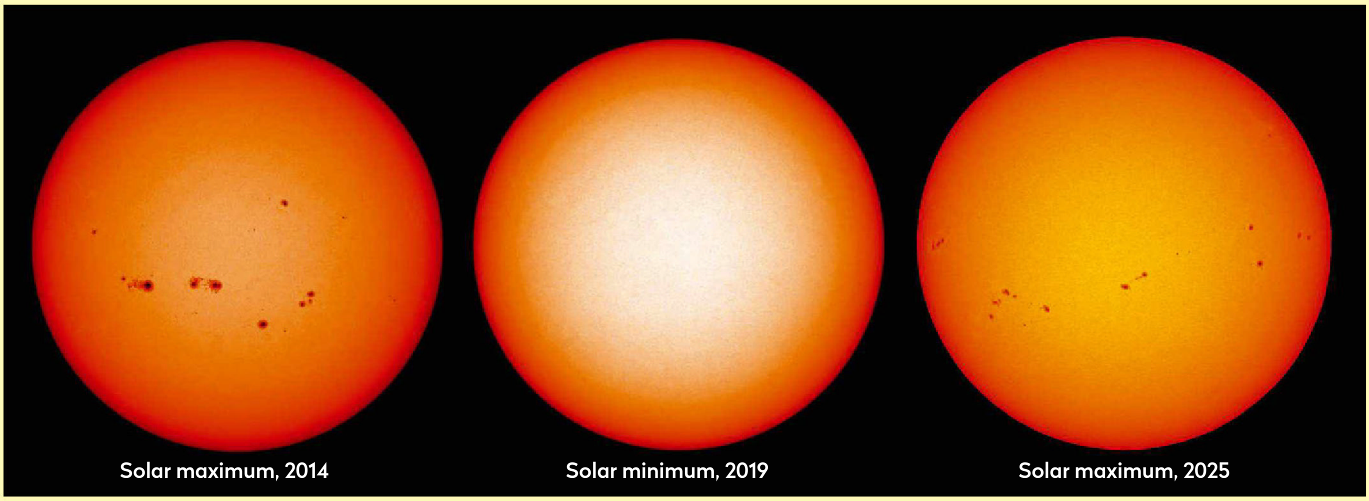
Now that MLAstro has made a ready-to-use consumer spectroheliograph, the SHG 700, it's

Solar cycle explained

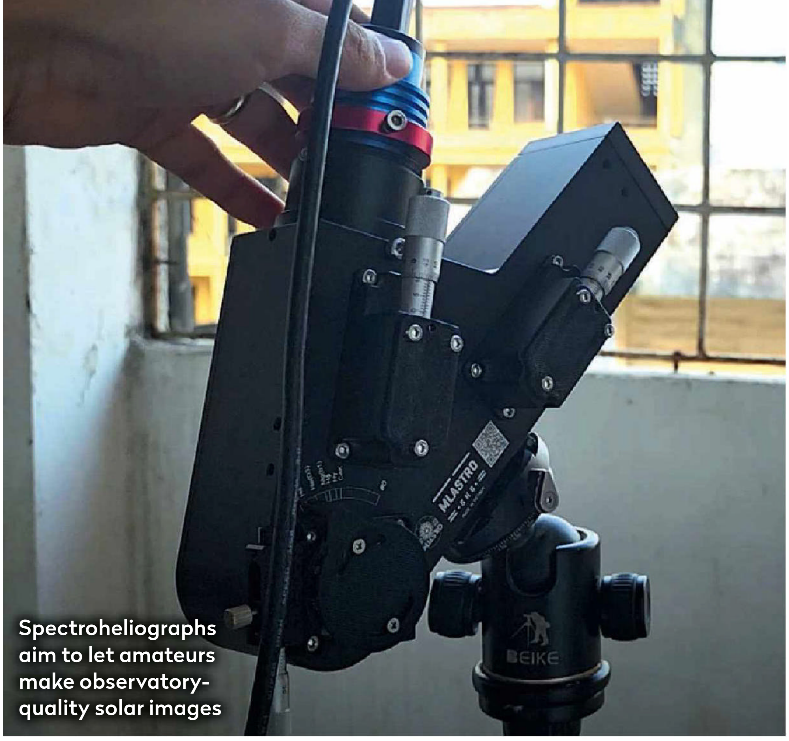
A surge in the Sun's activity makes it the perfect time to get into solar observing

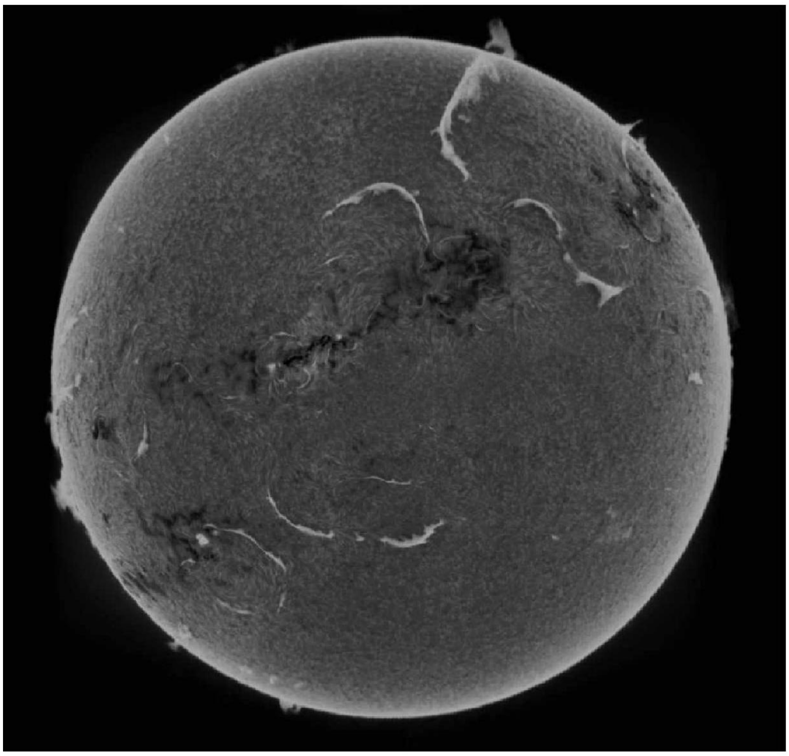
Since way back in the mid-1800s, both scientists and amateur observers have been keeping records of sunspots and, over time, a pattern began to emerge. The frequency of sunspots that appear on the Sun rises and falls cyclically over an 11-year period known as the solar cycle. The Sun is currently in Solar Cycle 25, which means this is the 25th cycle since records began. It is also at solar maximum, which is why the Sun is so active at the moment and also why we're seeing increased aurora displays around the world.

Solar cycles can be large or small, and normally a few large cycles are followed by a few small cycles. At the peak of solar cycles, the frequency of solar flares and coronal mass ejections, as well as sunspots, increases, as does the amount of light that the Sun emits. Yet it's never possible to definitively say exactly when solar maximum occurs until we have passed that point – which is what makes recording sunspots and other solar activity, as an amateur or a professional, such a valuable insight into our host star.



▲ **Every 11 years or so, the Sun's magnetic poles flip and the Sun reaches its maximum phase, becoming more active and stormy**


Spectroheliographs aim to let amateurs make observatory-quality solar images


▲ A stunningly detailed Sun image compiled from slices of high-resolution video captured by a spectroheliograph

possible to attach this device to a small refractor and record observatory-quality solar images in any wavelength, with extreme resolution and passbands in the 0.2 angstrom range.

It captures hundreds of 'slices' of the Sun using a high-speed astronomy camera at any wavelength desired and recombines these slices into a full-disc image. It takes a little getting used to and is not usable for visual observing, but there is no other device out there capable of producing these perfectly evenly illuminated images in such high resolution across the entire solar spectrum. Personally, I believe spectroheliographs to be the future of the solar astronomy hobby, that will eventually evolve into a fully automated imaging device that even a 10-year-old could use with great success.

Why study our Sun? What makes this hobby so special? There's nothing in our Universe more important to our survival as a species than this little G-type main sequence star that we call Sol. It is responsible for the evolution of life on our planet and its relative nuclear fusion stability is the reason we all exist. Earth receives enough energy continuously from the Sun (approximately 173,000 terawatts) to power all of humanity for about 10,000 years, and that's a conservative estimate.

> *"I believe spectroheliographs to be the future of the solar astronomy hobby"*

Your ringside seat on a star

The Sun is about halfway through its predicted 10-billion-year lifespan. When it dies, it will go through a red dwarf stage, probably vaporising the inner planets (including Earth) and ending its life as a planetary nebula much like M57, the Ring Nebula.

The Sun converts about 620 million tonnes of hydrogen into about 616 million tonnes of helium every second. Energy from its core is manifested as the solar wind, which strikes our planet and produces wonderful aurorae at the poles. Everything you have ever seen, photographed or sketched in natural light was lit because of that nuclear fusion over 93 million miles away, creating light that took 8.5 minutes to reach you.

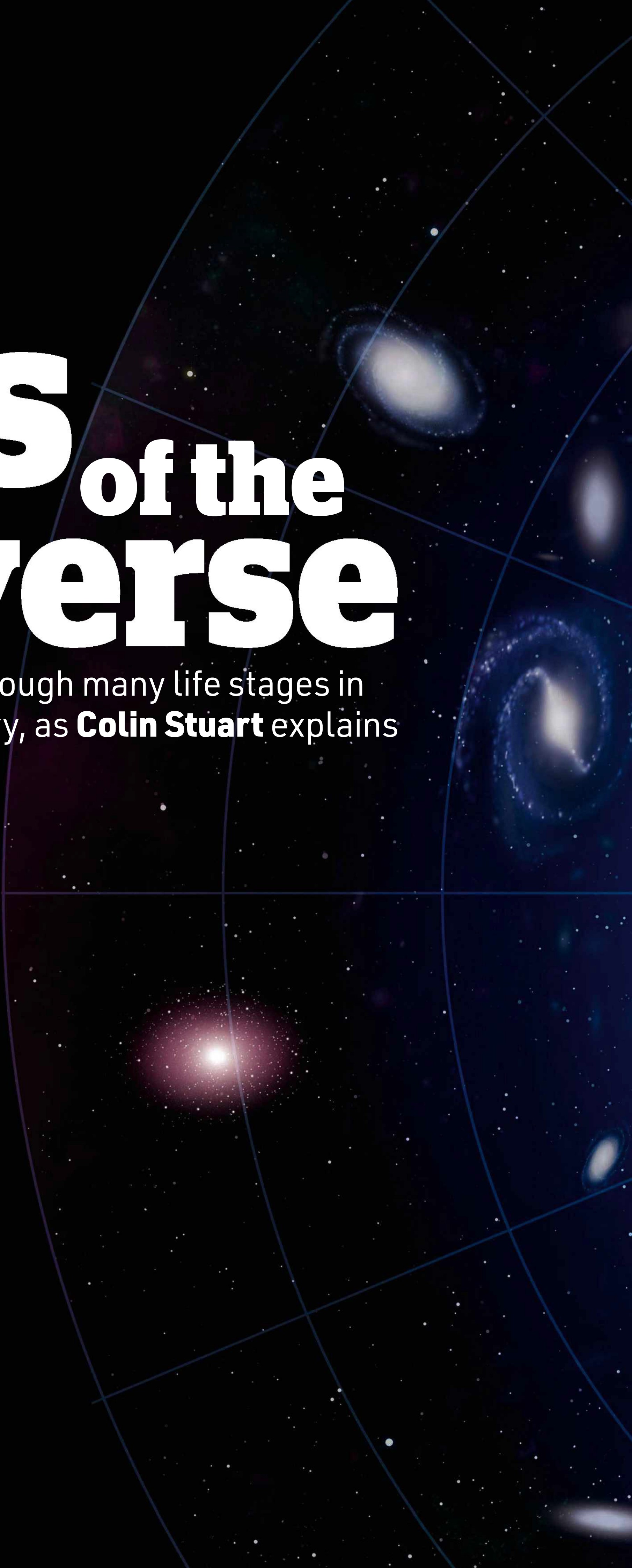
This is what makes solar observing so fascinating: seeing up-close the visible effect of what's going on beneath the surface of a star. As you progress with the hobby, it's good practice to observe regularly and note down what you see, as you'll create a record of how the Sun changes over time that becomes a genuine piece of science (see 'Become a solar scientist', page 62). And, it being a daytime activity, it's easy to spread the bug. Take your kit to a local park and show others the beauty of our Sun up close. It's a captivating hobby that gives us a real appreciation of the humble star that's the source of all life on Earth.

Stephen W Ramsden is the founder and director of the non-profit Charlie Bates Solar Astronomy Project. Find out more at **charliebates.org** or **imagethesun.com**

STEPHEN W. RAMSDEN X 2, SOLAR CYCLE: NASA'S SOLAR DYNAMICS OBSERVATORY/JOY NG/, MALCOLM PARK/ALAMY STOCK PHOTO, MLASTRO IMAGES: MLASTRO X 2

The eras of the Universe

Our Universe has gone through many life stages in its 13.8-billion-year history, as **Colin Stuart** explains



When Shakespeare came to contemplate the time and tides of human existence, he had Jaques in *As You Like It* speak of a man's life split into seven distinct ages: infant, schoolboy, lover, soldier, justice, pantaloon and old age.

The Universe itself is no different. Its tumultuous history can be also be broken down into eras. It is a story that starts with a fiery childhood, followed by the growing pains of adolescence and the wild abandon of a mid-life crisis.

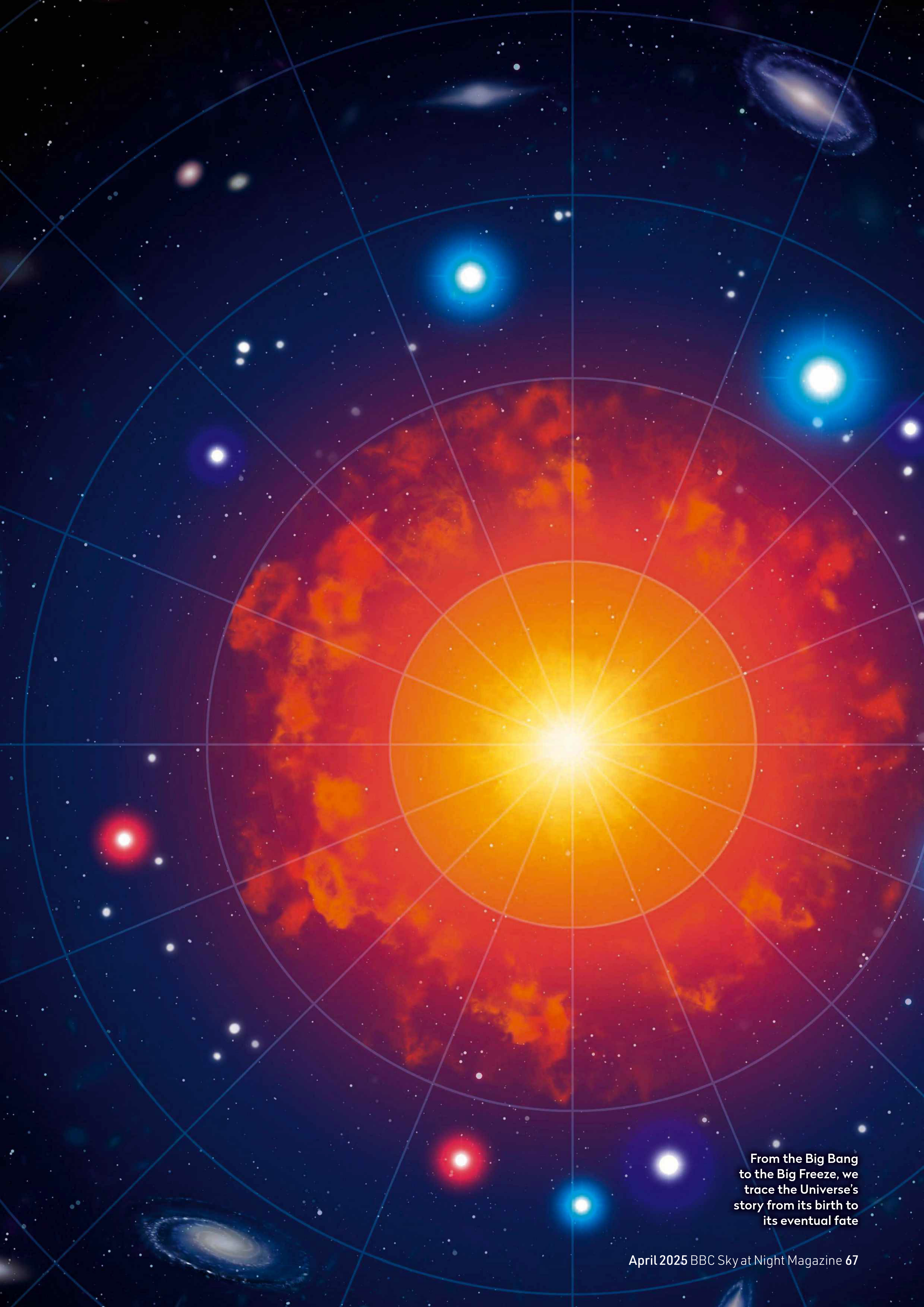
Let's explore these chapters in its life as we take a trip through the history of the Universe.

The first fraction of a second

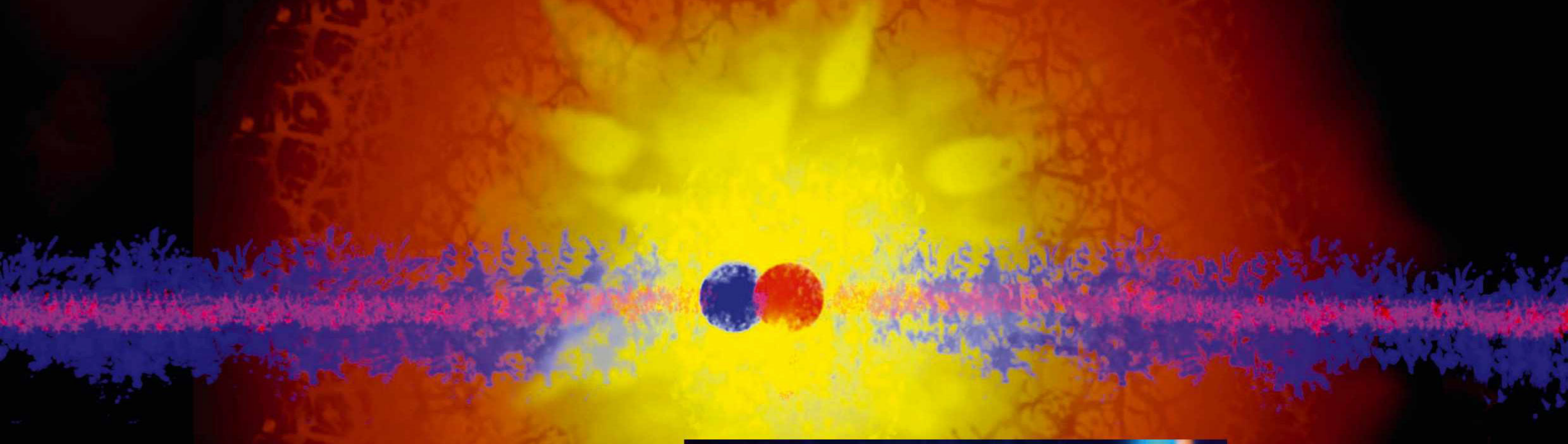
It's often said that our earliest experiences shape the people we become. This is definitely true of the cosmos. According to the latest theories, our Universe underwent a colossal growth spurt in its first sliver of a second. This effect – known as inflation – saw the Universe's size skyrocket from considerably smaller than an atom to the size of a grapefruit.

That may not sound like much, but it is. The Universe's volume suddenly got a million trillion trillion trillion trillion trillion trillion times bigger in a trillionth of a trillionth of a trillionth of a second. Take an ordinary shipping container and increase its size by the same amount and it would be bigger than the entire observable Universe. ▶

ILLUSTRATION: MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO



From the Big Bang to the Big Freeze, we trace the Universe's story from its birth to its eventual fate



▲ Matter and antimatter filled the Universe, with particles and antiparticles continuously being created and annihilated

▶ "Due to this rapid expansion, very small quantum fluctuations suddenly stretched," says Professor Kazuya Koyama, from the University of Portsmouth. Frozen into the Universe for good, these magnified fluctuations would become slightly denser and sparser regions. They were the seeds that would much later become the vast superclusters and supervoids we see in the Universe today.

Initially, the fundamental forces – the strong, weak and electromagnetic forces, and probably gravity – were all one. Yet, very quickly they peeled away from each other during this early era.

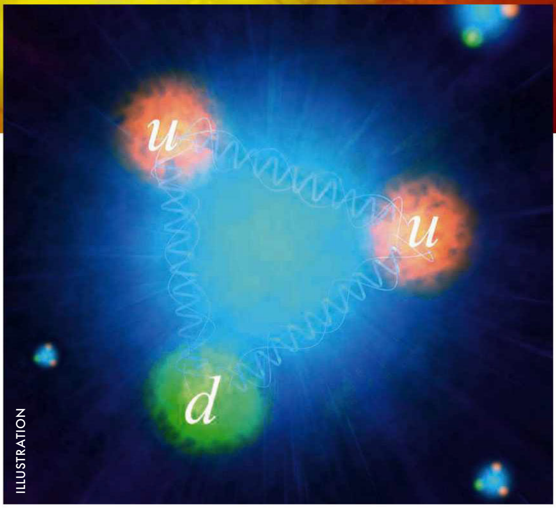
The first second

Before this point, the Universe was a sea of energy and subatomic particles. But as the Universe started to grow and cool a little, the particles slowed down and the newly separated fundamental forces were able to stick some of them together.

Particles called quarks found themselves bound into groups of three to form protons and neutrons. A solitary proton is the heart of a hydrogen atom, the simplest atom in the Universe, meaning the nucleus of the first element on the famous periodic table had appeared.

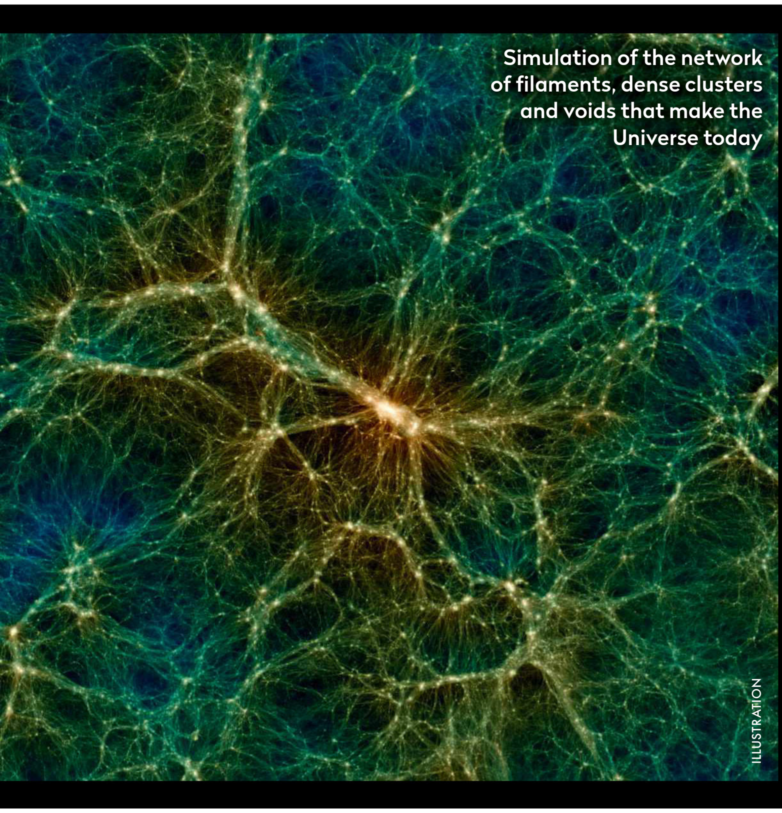
Hydrogen is a form of matter, but when energy turns into particles it creates equal quantities of matter and antimatter. For every quark, there should also have been an anti-quark.

When matter and antimatter meet, they destroy each other and turn back into energy. If matter and antimatter really were created equally within the



◀ In the first second, quarks began to bind together to form protons and neutrons, the basis of atoms

JAPATINO/GETTY, MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY, UCHUU PROJECT, NASA, ESA AND THE PLANCK COLLABORATION



Simulation of the network of filaments, dense clusters and voids that make the Universe today

The modern Universe

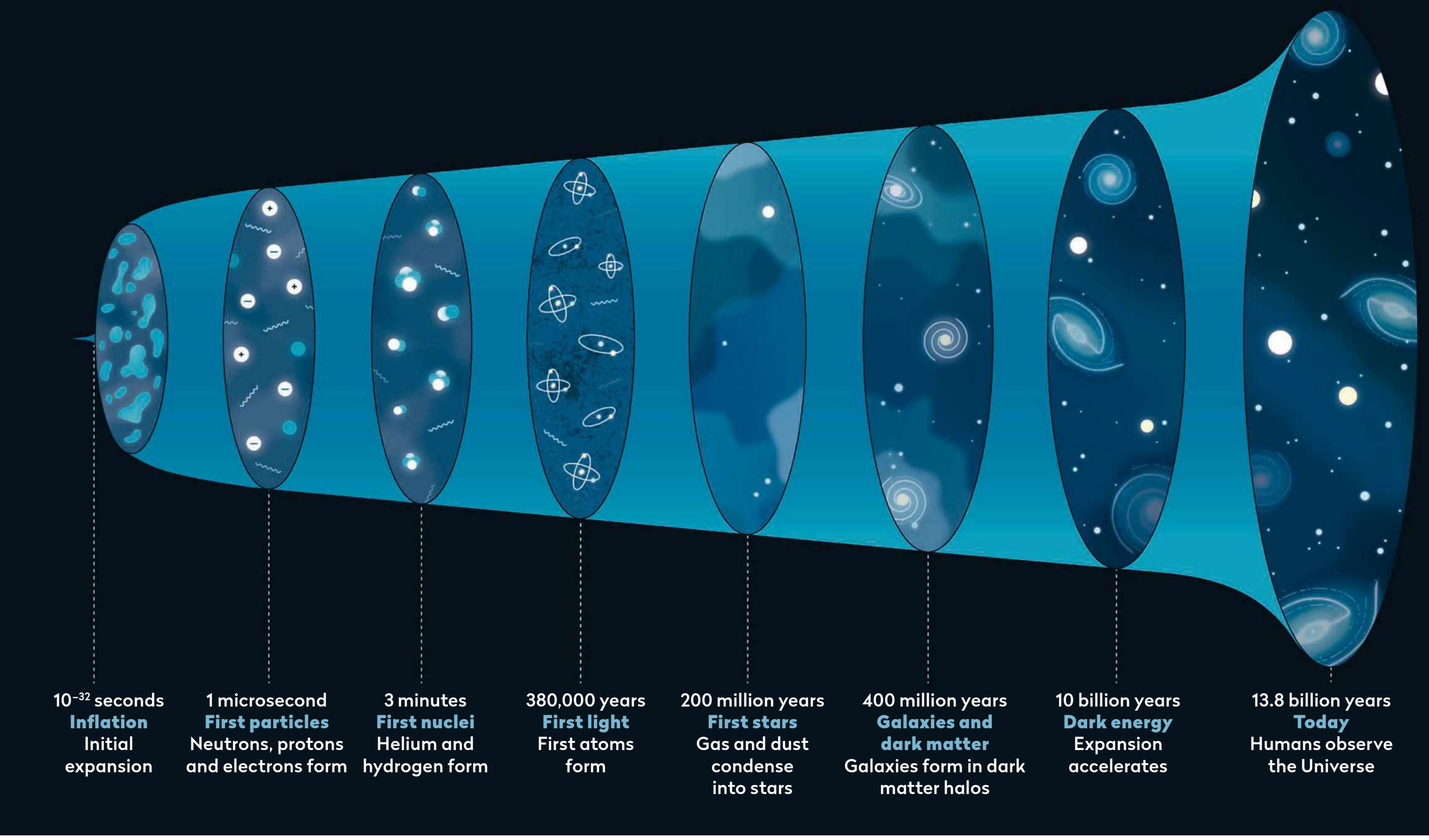
Our current era of the Universe looks very different to those that went before

One of the big differences between the early and modern Universe is how galaxies look. The first galaxies tended to be smaller and long and thin. Today's galaxies are usually either flat, spiral galaxies like our own Milky Way or rugby-ball-shaped elliptical galaxies.

Early galaxies also had a much higher rate of star formation. Today, only 4–8 Suns' worth of material is turned into stars within the Milky Way every year. In the earliest galaxies, it's more like hundreds of Suns' worth.

Over time, the structure of the Universe has also become more intricate. Today, the cosmos resembles a giant web, with vast filaments and superclusters of galaxies strung out like fairy lights on invisible cord of dark matter. Yet this took time to construct. Astronomers have spotted the first proto-superclusters – the initial building blocks of superclusters – beginning to form around 2.3 billion years after the Big Bang.

Planets would have been different too. Early planets were likely to have been gas giants like Jupiter and Saturn, because only hydrogen and helium were around. As new generations of stars then came and went, they made and then spread heavier elements such as iron, which typically forms the core of rocky planets.


10^{-32} seconds
Inflation
Initial expansion
1 microsecond
First particles
Neutrons, protons and electrons form
3 minutes
First nuclei
Helium and hydrogen form
380,000 years
First light
First atoms form
200 million years
First stars
Gas and dust condense into stars
400 million years
Galaxies and dark matter
Galaxies form in dark matter halos
10 billion years
Dark energy
Expansion accelerates
13.8 billion years
Today
Humans observe the Universe

▲ The Universe's eras of expansion and formation, from the first second to the present day

first second, then both should have disappeared completely by the time we reach the present day.

Instead, astronomers suspect that the infant Universe had a slight bias for matter. For every billion antimatter particles made in the first second after the Big Bang, a billion and one matter particles appeared. All the antimatter then disappeared along with almost all the matter. Stars, planets – and even ourselves – are made from this tiny residue of matter.

The first 20 minutes

Once hydrogen had appeared, a new construction mechanism was possible: fusion, the same process that powers the Sun. Every second, the Sun turns 620 million tonnes of hydrogen into 616 million tonnes of helium. The 'missing' tonnes are converted into sunshine.

The process starts when two protons – the nuclei of hydrogen atoms – fuse, or stick together. Yet both particles are positively charged. As with matching magnetic poles, their natural instinct is to repel one another. This desire can only be overturned by extremes of temperature and pressure that force them together anyway. Today, those conditions are only found inside stars. Yet in the first 20 minutes after the Big Bang, the Universe itself was hot enough for fusion. After 20 minutes, though, the Universe had further expanded, dropping the temperature and switching hydrogen fusion off. This left behind a Universe made of 75 per cent hydrogen and 25 per cent helium (by mass).

Things did rumble on a little further, though. "One in a million [atomic nuclei] were still being created even a day after the Big Bang," says Ryan Cooke at Durham University. These include heavier versions of hydrogen, such as deuterium and tritium, plus helium-3 and beryllium-7.

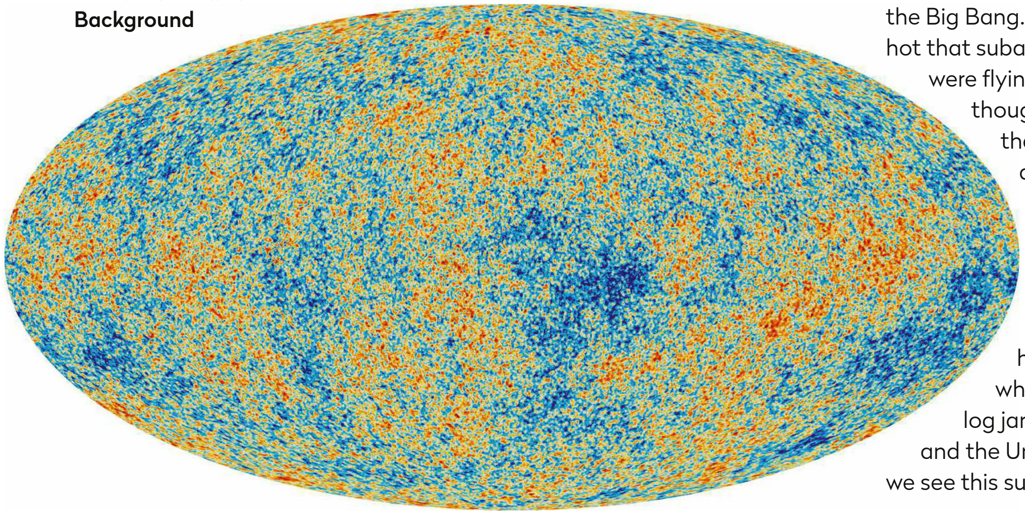
The first 380,000 years

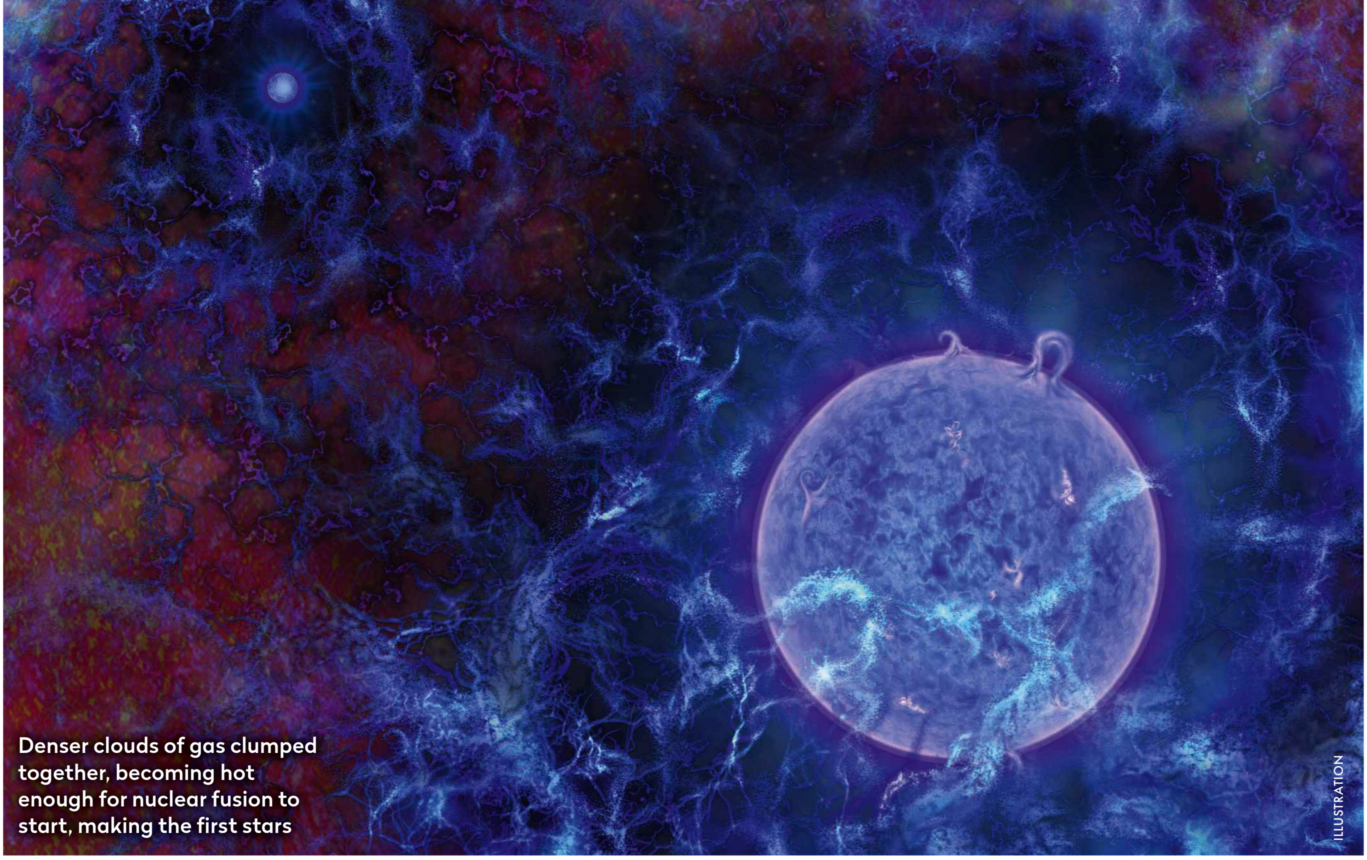
Next, the Universe underwent a period that can only be likened to the tumbleweed in old Western movies. Nothing much happened. The Universe was too cool to make new particles or to fuse existing particles.

Things changed some 380,000 years after the Big Bang. Previously, the Universe was so hot that subatomic particles called electrons were flying around at breakneck speed. Now, though, the Universe had cooled enough that nuclei could grab passing electrons and bind to them. The first complete atoms formed in an event known as 'recombination'.

With electrons now tucked away, suddenly there was a lot more empty space between atoms. The light that had been left over from the Big Bang, which had previously been trapped by the log jam, was now free to stream outwards and the Universe became transparent. Today we see this sudden release of energy as the Cosmic ▶

▼ The afterglow of the Big Bang is still visible today as the Cosmic Microwave Background





Denser clouds of gas clumped together, becoming hot enough for nuclear fusion to start, making the first stars

NICOLLE R. FULLER/NATIONAL SCIENCE FOUNDATION, MARK GARLICK/ SCIENCE PHOTO LIBRARY/GETTY, ESO, NASA'S GODDARD SPACE FLIGHT CENTER

▶ Microwave Background (CMB). If the Universe were an 80-year-old person, the CMB is a snapshot of it at just 19 hours old.

"The CMB has small temperature variations, about one part in 100,000," says Koyama. These correspond to the tiny quantum fluctuations that were magnified by inflation right at the start of the Universe.

One billion years

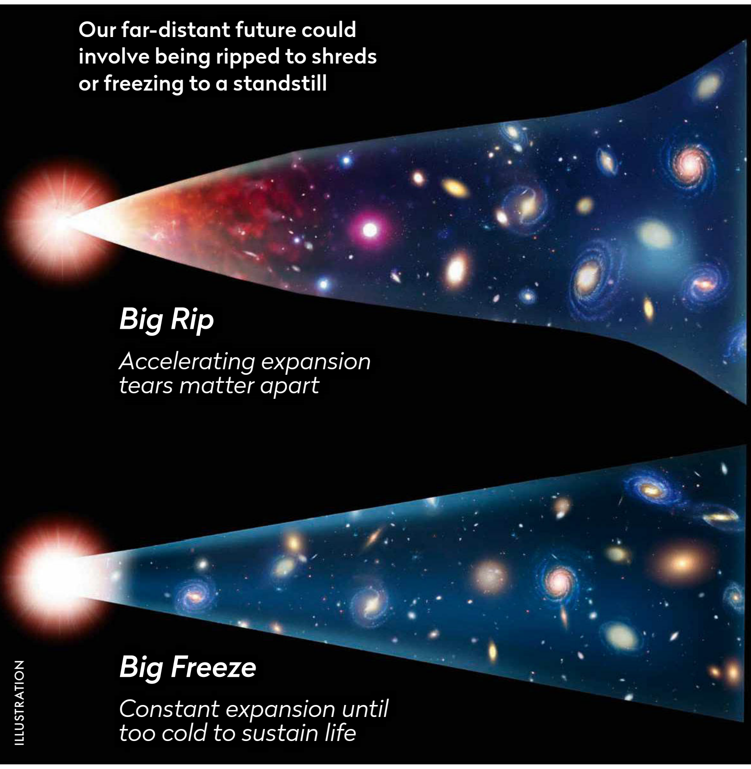
Astronomers are still unsure as to when exactly the first stars appeared, but it is usually pegged at within the first few hundred million years after the Big Bang. Efforts have been made to find the first stars in early galaxies, but they can't be seen directly because there was too much gas and dust in the way of their light. They also lived fast and died young, within just a few million years.

Instead, astronomers look for the way they polluted the gas clouds around them with the by-products of fusion: elements heavier than hydrogen and helium, formed via the fusion in the heart of these stars. "It's like a crime scene," says Cooke. "We're looking for the unique fingerprint of the first stars."

Upcoming telescopes could be a real game-changer in this regard. The Extremely Large Telescope, for example, currently set for completion in 2028, will have 100 times the light-gathering power of the Hubble Space Telescope.

Colin Stuart (@skyponderer) is an astronomy author and speaker. Get a free e-book at colinstuart.net/ebook

Our far-distant future could involve being ripped to shreds or freezing to a standstill


Big Rip
Accelerating expansion tears matter apart
Big Freeze
Constant expansion until too cold to sustain life

ILLUSTRATION

What comes next?

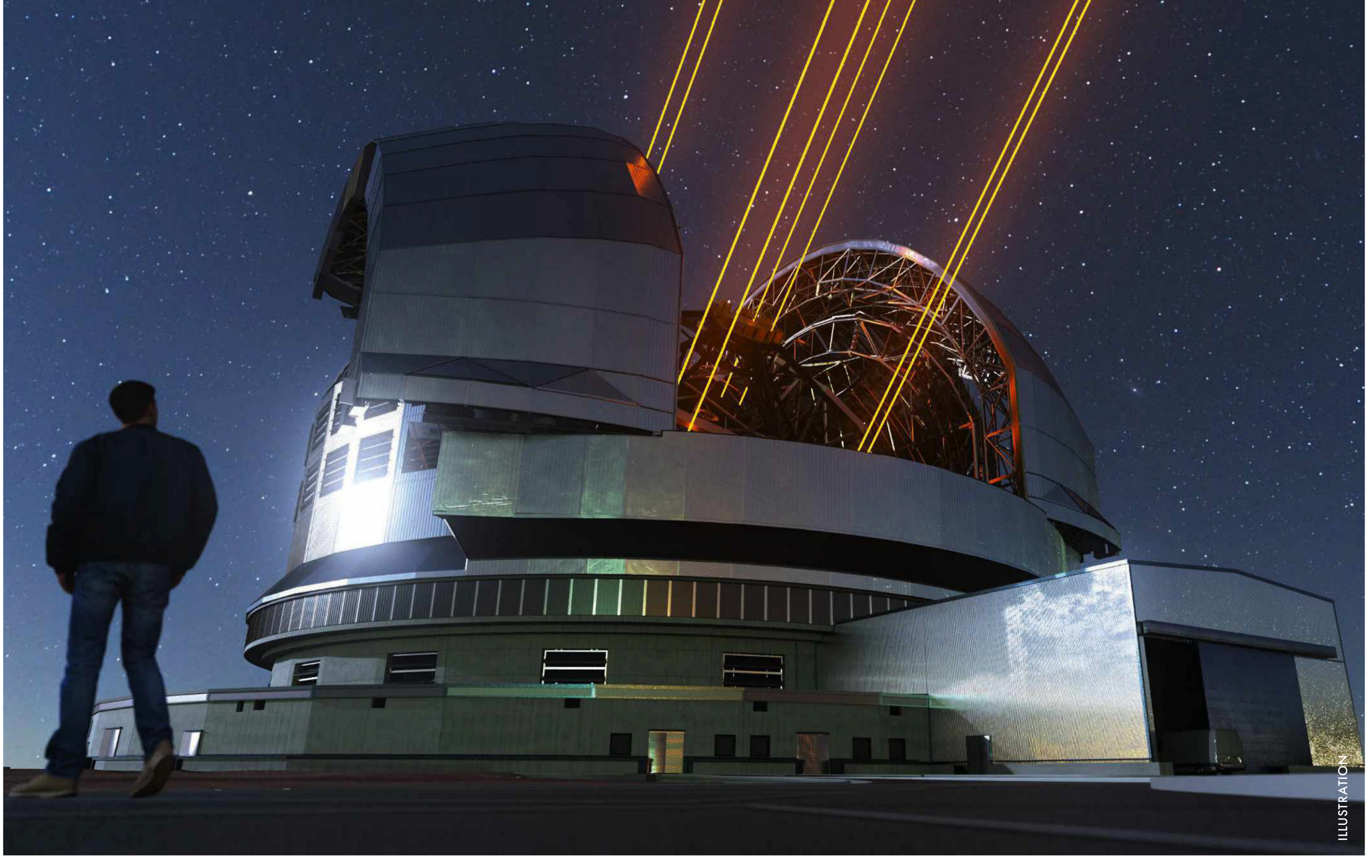
Our Universe's fate most likely depends on what dark energy is and what it does in the future

While astronomers don't yet know what dark energy really is, it seems it will continue to drive the accelerating expansion of the Universe. One day, the space between stars will be stretched so much that galaxies are torn apart. Then the expanding space between planets will shred entire solar systems. Eventually, the space between electrons and atomic nuclei will be dragged out to such a degree that even atoms can no longer exist.

Astronomers call this calamity the Big Rip. In around 22 billion years' time, the Universe will contain no stars, planets, atoms or lifeforms – an empty, barren cosmic wasteland.

This only happens, though, if dark energy continues to be ever more potent. If instead the Universe continues to expand at a steady rate, then we're looking at the so-called Big Freeze instead. Everything in the Universe will be so far apart that all energy is evenly distributed. The Universe will cool to absolute zero (–273°C/ –460°F) and all biology and chemistry will cease to exist.

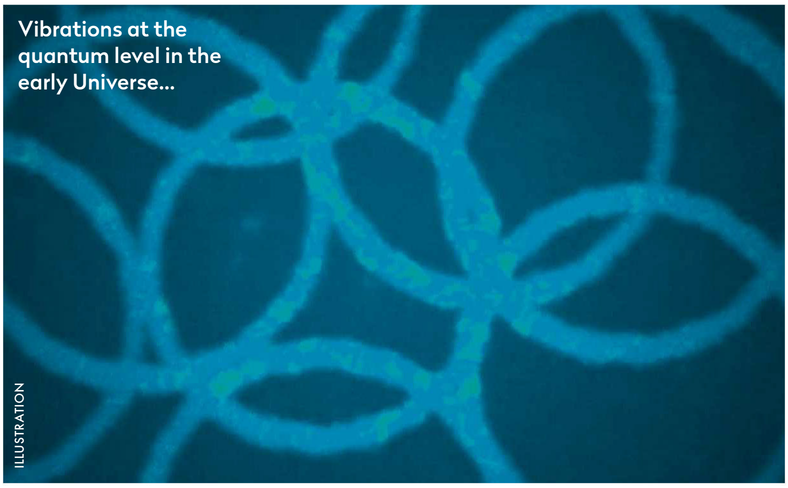
We're looking super-far into the future, though. Estimates for the number of years until the Big Freeze tend to be around 1 with 100 zeros after it.

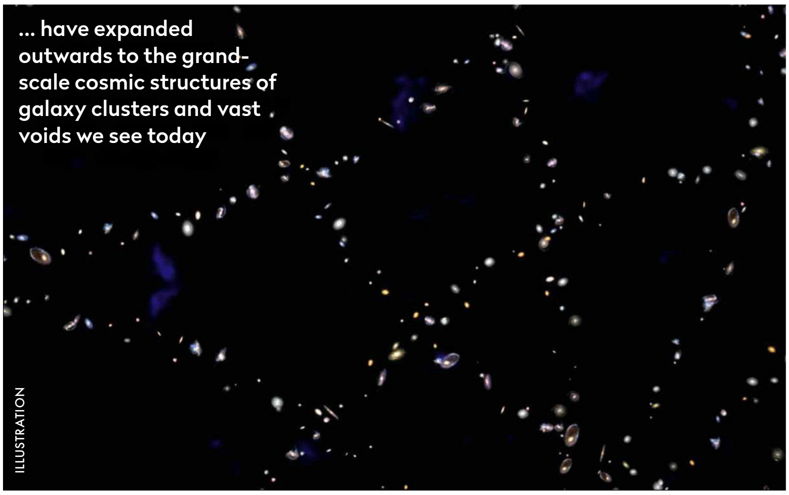


▲ **The Extremely Large Telescope will study the earliest stars, almost as old as the Universe itself**

Solving this particular celestial whodunnit is important work. "It was one of the most transformative times in the Universe's history," says Cooke. "It went from being dark, to all of a sudden the first star igniting and creating most of the elements in the periodic table other than hydrogen and helium." In other words, the first stars kick-started huge chemical changes in the Universe that made stars like the Sun – and planets like Earth – possible.

It's also around this time that the very beginning of the modern-day structure of the Universe, with its sprawling superclusters and supervoids, tentatively began to take shape, building on the seeds sown during the Universe's early inflationary era.


Vibrations at the quantum level in the early Universe...


... have expanded outwards to the grand-scale cosmic structures of galaxy clusters and vast voids we see today

Nine billion years

Aeons on from the Big Bang and you might expect, as most astronomers did, that the Universe's expansion would be slowing. But there came an almighty shock. In 1998, two separate research teams reached the same staggering conclusion: not only is the Universe's expansion not slowing down, it's actually gathering pace. What could be driving this acceleration? Astronomers don't yet know, so they call it 'dark energy'. What could it be?

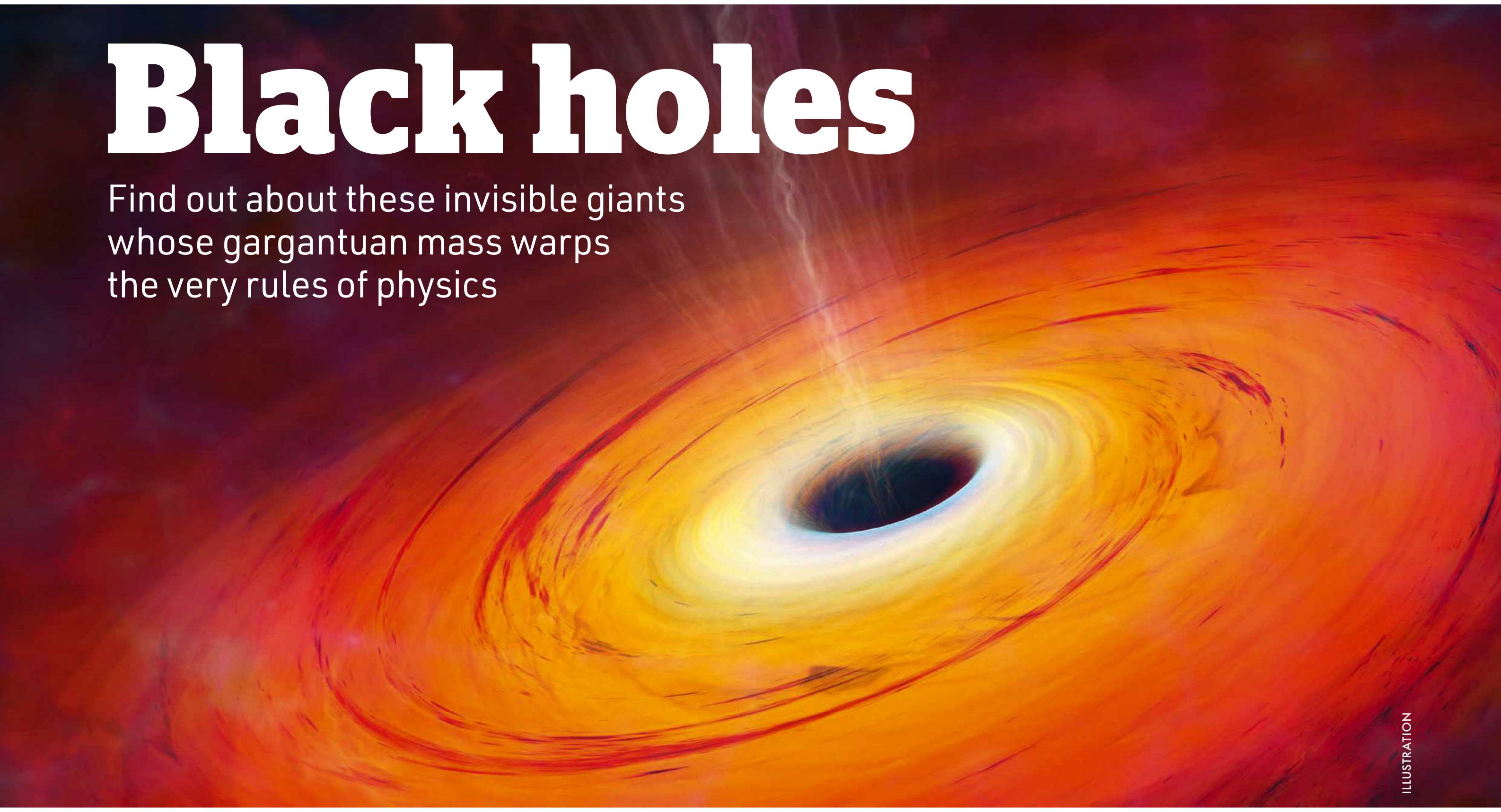
"The first option is what's called the cosmological constant," says Koyama. The idea is that even empty space has an intrinsic property that works to counteract gravity. As the name suggests, the strength of this energy remains constant. But as the Universe expands and galaxies move further apart, the collective strength of their gravitational attraction diminishes. There came a point, around five billion years ago, when suddenly the strength of this attraction dipped below the might of the cosmological constant. Unshackled, the Universe's expansion began to accelerate away.

Tantalisingly, however, Koyama says recent findings suggest that dark energy isn't constant after all. Instead, whatever it is has become stronger over time.

"It's just a hint," Koyama says. "We need more evidence to be sure." That data could soon be on the way, thanks to the Dark Energy Spectroscopic Instrument (DESI), the Euclid telescope and the upcoming Nancy Grace Roman Space Telescope. Their observations could be key to predicting what the next era of our Universe will be.

The fundamentals of astronomy for beginners

EXPLAINER



Black holes

Find out about these invisible giants whose gargantuan mass warps the very rules of physics

Although they could be considered the stuff of terrifying science fiction, in reality black holes are common throughout the Universe. They aren't really holes, portals or cosmic vacuums either: instead, they're the result of infinitely dense points, which cause spacetime to warp around them so that not even light can escape.

Black holes range in size from those with masses a few times that of our Sun to giants with billions of times that mass. At the lighter end are stellar-mass black holes, the last stage of stellar evolution for massive stars. When these massive balls of gas run out of fuel, they no longer experience an outwards pressure resisting the pull of their own gravity. They collapse, creating a singularity – a point of infinite density – while their outer layers rebound in a supernova explosion. This is a stellar-mass black hole, which is typically five to 10 times the mass of our own Sun. Like many stars, these can exist in binary systems and are found throughout the Galaxy.

Intermediate-mass black holes are much bigger, at around 100 to 100,000 times the mass of our Sun. These are thought to be too big to be the result of a star's collapse. Instead, scientists theorise they could come about through several stellar-mass black holes merging, or from the collision of multiple massive stars in globular clusters.

▲ Black holes aren't really holes but areas in space packed with so much matter that their gravity lets nothing escape, including light – hence the name

The largest are supermassive black holes, which are millions or even billions of times the mass of our Sun and lie at the centre of every galaxy. Our own Galaxy, the Milky Way, contains Sagittarius A* (Sgr A*), which is 10 million times more massive than our Sun. Its name comes from the fact that it was first observed as a mysterious radio source in the constellation of Sagittarius. By the 1980s, it was considered likely to be a black hole, and that was confirmed by Andrea Gherz and Reinhard Genzel, who won the Nobel prize for the discovery in 2020.

Where black holes come from

The origin of supermassive black holes is still uncertain, but observations of very distant (and therefore very old) galaxies show that they existed within the first billion years of the Universe. There are two main theories: either they began from the black

MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY, MIT HAYSTACK OBSERVATORY, PITRIS/GETTY, EHT COLLABORATION

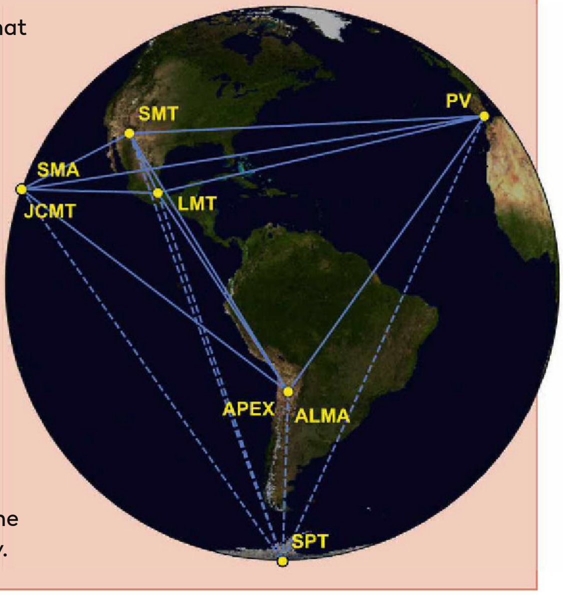
Seeing the unseeable

Astronomers are peering ever closer to a black hole's invisible heart

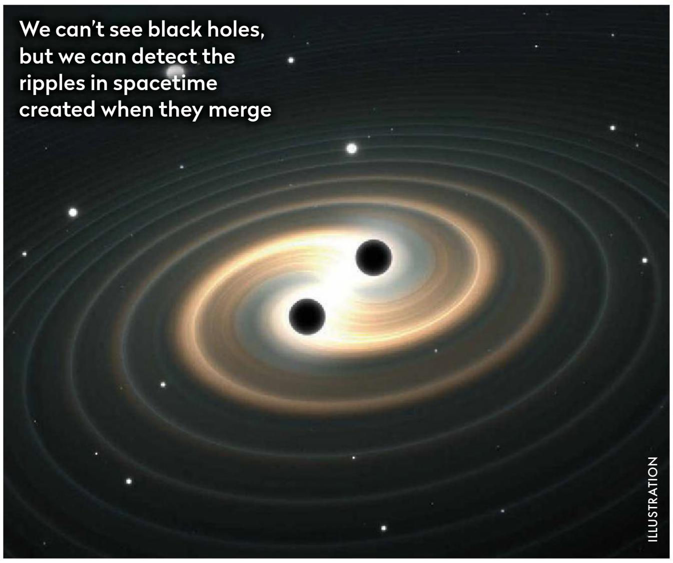
As bodies move through the Universe, they emit gravitational waves that stretch and squeeze anything they pass through by a tiny amount. When two black holes merge, they create immense gravitational radiation, which can be picked up by gravitational-wave detectors on Earth.

These detectors have two 4km-long (2.5-mile) arms. Light travels down each arm and is reflected back at the end, before both beams are picked up by the detector. By comparing the two light beams using a technique called interferometry, the detector can see if they've been stretched or squeezed by passing gravitational waves. This allows astronomers to reveal the properties of the black holes that created the waves.

In 2019, the first direct images of a black hole were taken by the Event Horizon Telescope (EHT). This is a global network of up to 11 radio telescopes, working together to create a telescope with the effective diameter of Earth. As the angular resolution of a telescope depends on its diameter, this was able to resolve the 'shadow' of a black hole's event horizon. The team were able to capture the supermassive black hole in giant galaxy M87, as well as the one at the heart of our own Milky Way Galaxy.

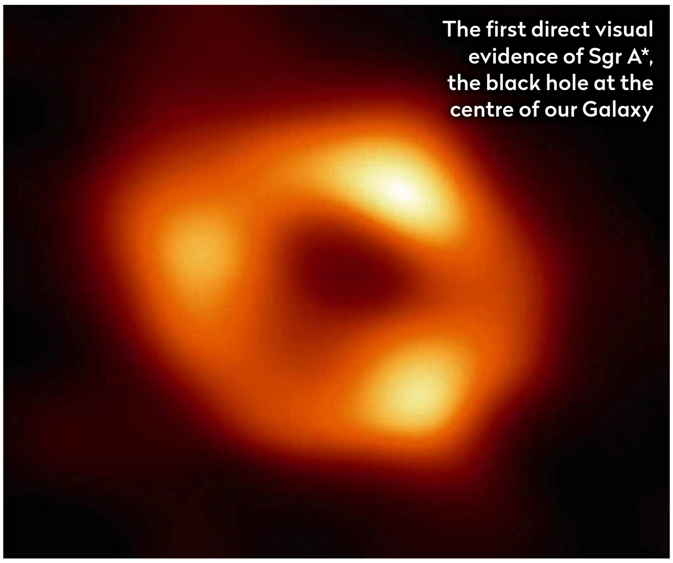


▼ The EHT is comprised of radio telescopes in France, Spain, Greenland, Chile, the USA, Mexico and the South Pole



We can't see black holes, but we can detect the ripples in spacetime created when they merge

ILLUSTRATION



The first direct visual evidence of Sgr A*, the black hole at the centre of our Galaxy

holes left by supermassive stars in the early Universe and grew over time, or they formed directly from the collapse of giant gas clouds. The most massive could be the result of two supermassive black holes merging in a violent collision of galaxies.

Black holes are difficult to observe, precisely because they're 'black' – they don't reflect light or emit it. Their gravitational pull is so extreme that beyond a certain point, the event horizon, not even light can escape the black hole. Any matter that crosses this point will inevitably end up at the singularity. As they don't emit light, we can only observe black holes indirectly, by measuring their effect on spacetime and on things we can see.

Around the event horizon, a swirling ring of hot gas and dust orbits the black hole: the accretion disc. This ring is superheated because of the black hole's intense gravitational pull, which makes it 'glow' and emit electromagnetic radiation. At the 'last photon orbit', particles of light walk a narrow tightrope, skirting around the black hole without plunging into it. These are what cause the glowing orange doughnuts visible in the famous images taken by the Event Horizon Telescope of Sgr A* at the centre of the Milky Way and M87* in the Messier 87 galaxy. Black holes can also produce relativistic jets as a result of feeding upon nearby stars, gas and dust. These near-lightspeed beams of particles and radiation extend far into space and are detected on Earth as sudden bursts of radiation as we cross the line of the beam.

Seeing images of black holes would have been unthinkable not so long ago. While they are still phenomena shrouded in mystery, who knows where the science might take us next?

Katie Sawers is a science writer and associate editor at IOP Publishing

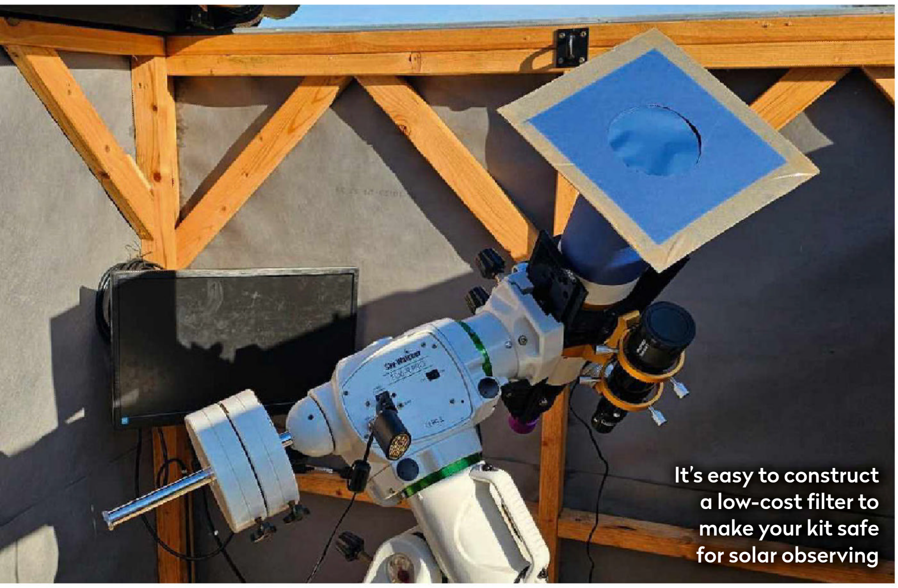
CAUTION
Don't look at the Sun directly with the naked eye or any unfiltered optical instruments

Practical astronomy projects for every level of expertise

DIY ASTRONOMY

Make a DIY solar filter

With solar action hotting up, get your DSLR or refractor ready and Sun-safe with this simple project


It's easy to construct a low-cost filter to make your kit safe for solar observing

Solar photography may feel out of reach to many, because viewing or imaging the Sun often involves specialist equipment. Solar telescopes have special coatings to block a large percentage of unwanted light from reaching your eye or your camera sensor. These can be combined with etalons, hydrogen-alpha (Hα), calcium-K (CaK) or white-light filters that allow you view the light emitted by certain elements. However, because of their specialist nature, all of these items tend to come with a high price tag.

But there is a simple, cost-effective way to retrofit your telescope or camera lens to make it Sun-friendly: a DIY solar filter. For this, we use solar safety film, a special film that blocks enough light to allow you to safely view or photograph the Sun. The sheet of silvery plastic is designed to be cut and built into home-made frames that pop onto the end of your camera lens or telescope.

For this one, I used Baader Astrosolar Safety Film, but other astronomy manufacturers make similar types. This film is available in two strengths: neutral density 5.0 for visual use and 3.8 for photographic use. The stronger 5.0 can also be used for photography, but will require longer exposure times than the 3.8 version. Unlike expensive hydrogen-alpha solar telescopes, this type of solar film will only allow you to see the Sun in white light, so will not show prominences, but it will allow you to see sunspots and some surface details.

ALL PICTURES: CHRIS GRIMMER

Chris Grimmer is an experienced astrophotographer and photographer specialising in infrared images

When handling your solar film, it's important that you don't touch the film directly to avoid ripping, scratching or marking it with grease from your fingers. You need to preserve its integrity to ensure that it's safe and optimised for solar use. Make sure to use the protective film it arrives sandwiched between, only removing this when it's time to tape the solar film into place on the card.

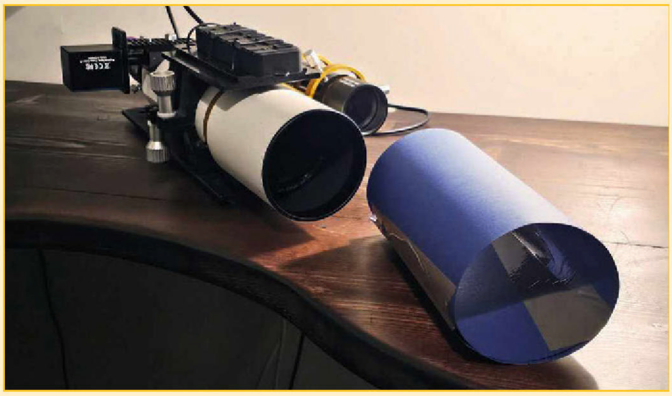
To further preserve the solar film's properties, don't stretch it when fixing it into your homemade frame. Don't worry if the film doesn't sit flat or has some wrinkles – this will not affect the views in any way. When attaching the sleeve to the filter holder, cutting the end of the sleeve into thin strips will allow you to fold the cardboard back while maintaining the sleeve's shape and will also make it easier to stick everything firmly together.

Once completed, the filter will need to be protected between uses. Keep it in a safe place, such as a solid airtight container, and carefully inspect it for damage before and after each use. If you have any concerns about the film, discard it and don't try to use it. Under no circumstances should you try to observe or image the Sun without using specialist equipment, as this can cause severe injury, as well as damage to your equipment. While this filter will allow safe observation of the Sun, care is still needed to avoid accidents.

What you'll need

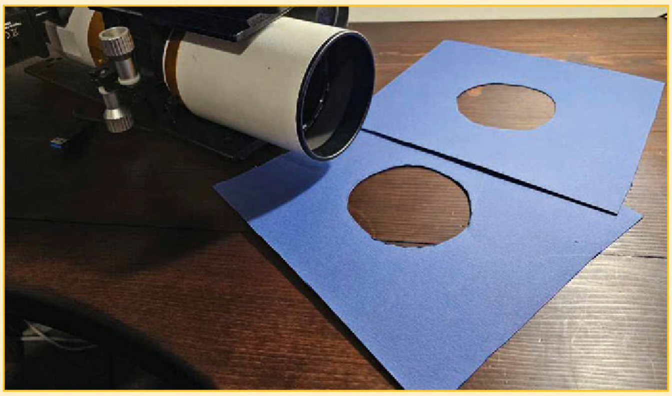
- ▶ Solar film from a certified manufacturer
- ▶ Strong but flexible cardboard, such as a cereal box
- ▶ Wide tape, such as parcel tape
- ▶ Tape measure
- ▶ Sticky tape
- ▶ Sharp scissors
- ▶ Superglue
- ▶ Pen or pencil

Step by step



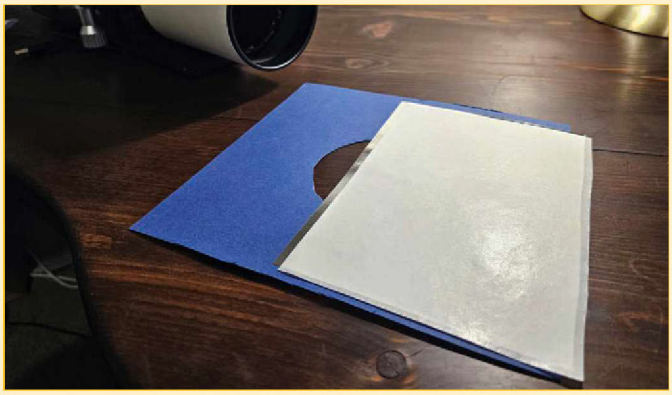
Step 1

First, make the sleeve that will hold the finished filter onto the telescope. Ensuring the card is wide enough to fit securely onto your scope's tube (you can trim it later), secure the seam with tape. Remove the sleeve and add tape to the inside seam.



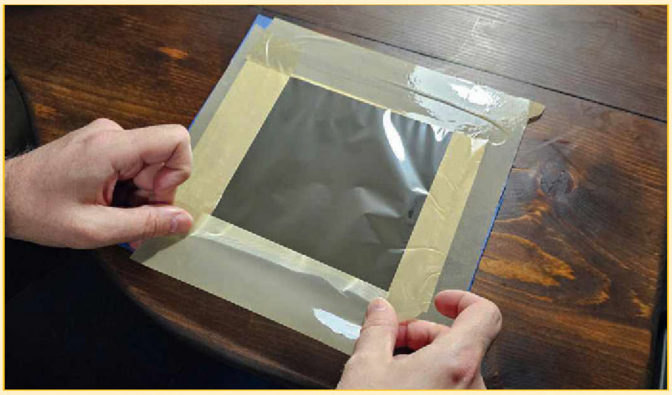
Step 2

For the front element, cut two equal-sized squares of card, each a few inches wider than the aperture of your telescope. Use a tape measure to find the centre of each piece, then cut out a circular hole slightly smaller than the aperture of your scope.



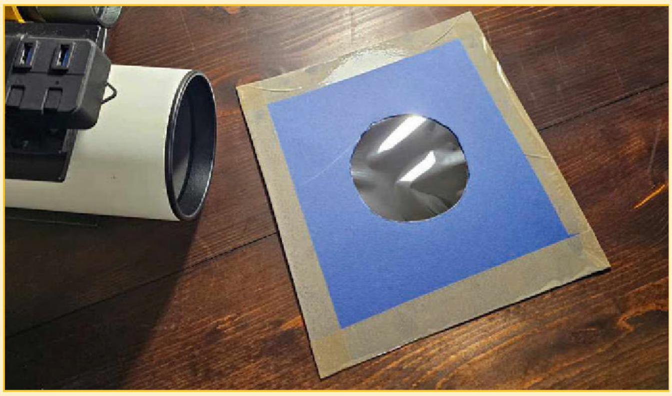
Step 3

With care, cut your solar film, ensuring that it's larger than the aperture of the holes you just created. You need this additional space in order to tape the film down without risking any of the tape intruding onto the useable filter area.



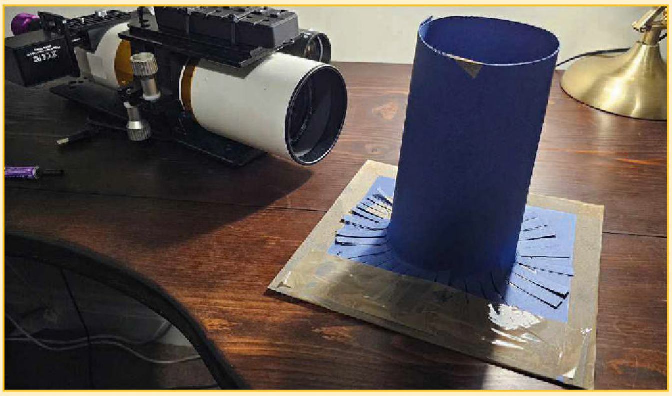
Step 4

Take one piece of the square card and place the film over its central hole. Use tape to fix the sides of the film in place, making sure tape isn't near the area you'll look through, to ensure the film maintains its integrity. Don't worry about any wrinkles.



Step 5

Take the second piece of card and sandwich the film between the two. Secure the edges with tape so that the film is held securely and safely. Turning back to the sleeve, make parallel cuts 1.5–2 inches long at one end of it and gently fold the card back.



Step 6

Apply glue to the back of the filter holder, carefully avoiding the film. Without touching the film, squash the cut-and-folded end of the sleeve onto the filter holder and hold until the glue has set. Further secure each edge with plenty of tape.

Take the perfect astrophoto with our step-by-step guide

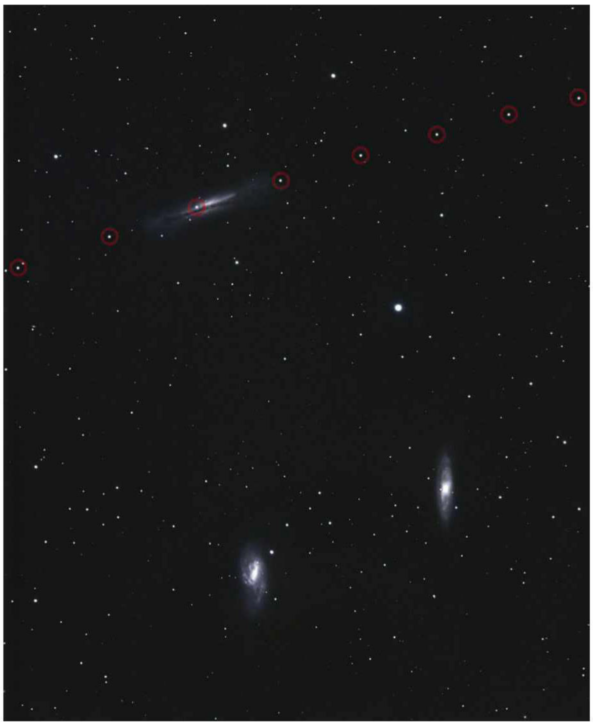
ASTROPHOTOGRAPHY CAPTURE

Catch Flora crossing the Leo Triplet

How to photograph the asteroid's passage to best effect – and avoid the Moon

There are lots of asteroids and lots of deep-sky objects. However, despite some of the latter being relatively large in size, events where asteroids pass in front of deep-sky objects are relatively infrequent. But this month, 8 Flora will appear to pass through the three galaxies that form the Leo Triplet. The Triplet includes M65, M66 and NGC 3628, which have integrated magnitudes of +9.3, +9.0 and +9.4, respectively. Bright though this seems, it is surface brightness that matters – how the light is spread over the apparent area of each galaxy. The respective values of surface brightness for the Triplet are +12.9, +12.8 and +13.5 magnitude per square arcminute.

Flora's passage through the Triplet isn't a perfect pass and will miss M65 and M66 completely. However, it will pass in front of dimmer NGC 3628, and this is the event that we're encouraging you to attempt this month.



▲ **Minor planet 8 Flora will pass in front of NGC 3628 in the Leo Triplet this month**

A few hurdles

If you think that recording a mag. +10.1 asteroid passing across a mag. +9.4 galaxy is an easy task, think again. As is often the case, the sky has a few hurdles it's going to throw your way. The unpredictable one is the weather, but assuming we have a bit of luck in this department, the next hurdle – and it's a big one – is the Moon. The crossing occurs on 9–12 April, Flora passing east to west across NGC 3628. The Moon on the evening of 9 April is a 91%-lit waxing gibbous and located, wouldn't you know it, just to the south of the Leo Triplet.

Over the course of the next few nights, the situation doesn't really improve that much. Although the Moon moves further from the Triplet, it also increases in phase, achieving full Moon on 13 April. This will be an issue when attempting to image a fuzzy, extended object like a galaxy. However, there is a way to overcome this limitation to a degree.

If your intention is to show the movement of 8 Flora over the period when it's crossing NGC 3628, then you would normally do this by creating a composite image: a base image showing the galaxy, or probably galaxies if you want to include the entire Triplet, together with frames showing the relative position of the asteroid over several nights. The important nights are 9 and 10 April, when the asteroid will be crossing over the galaxy itself. On these nights, continuous capture could be used to show the movement of Flora over the course of hours rather than days. However, again this would normally be assembled as a composite, the positional shots overlaid over a base image of NGC 3628.

In this instance, the base will need to be grabbed either earlier than the positional shots or even later. The key information will be stars and these are not as affected by moonlight as a diffuse object like a galaxy. So, despite the light-pollution wrecking ball that is the Moon crashing the party, it's still possible to reveal this infrequent passage to best effect. We just need to keep our fingers crossed that the weather is kind.

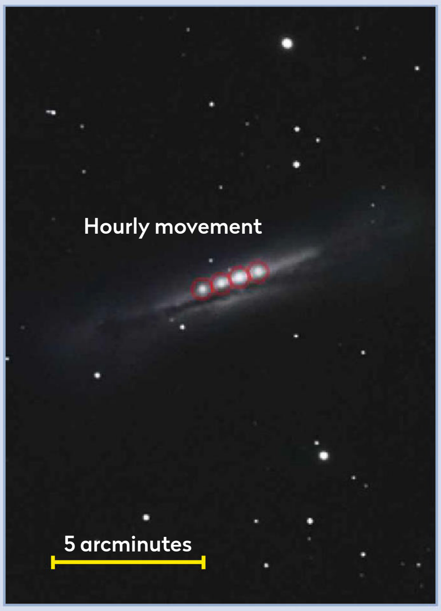
Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

Equipment: Small telescope, camera

✉ **Send your images to:**
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

Step by step



STEP 1

The first step is to decide on the area you want to cover. If you intend to use a camera with a photographic lens, it needs to have enough focal length to show the galaxies individually. A higher image scale will also make it easier to show Flora's movement and help keep the bright Moon's glare out of the shot.

STEP 2

The Moon will wreak havoc with any attempt to shoot the Triplet galaxies over the period of the crossing, introducing heavy glare gradients that will be hard to remove. The best strategy will be to image the galaxies before or after the event, producing a beauty shot of the Triplet onto which Flora's motion can be mapped.

STEP 3

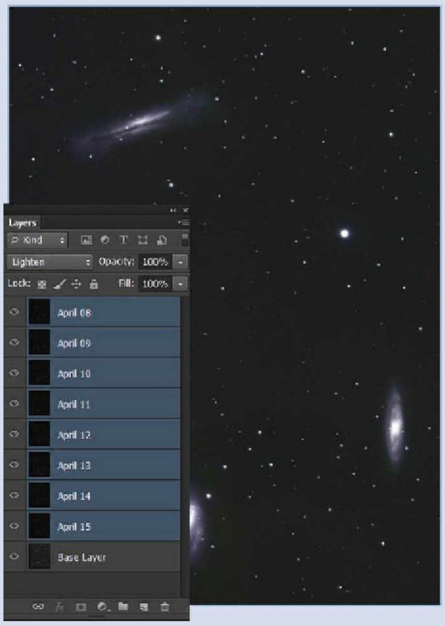
Use whatever means you have available to get your base shot. Ideally this should cover the entire Triplet. If you attempt to create this close to the crossing dates, be aware that Flora may also be in the frame. This isn't an issue, but it should ideally be identified to avoid confusing it with a star. Take your time and get the best base image possible.

STEP 4

Smart scope users have it easy for this event but again, we'd recommend creating a clean base image before or after the Moon has passed through the area to avoid any awkward gradient effects. Aim to do your captures when the Triplet is in more or less the same position relative to the horizon, say centred on 23:00 BST (22:00 UT) for the start of April.

STEP 5

For the crossing period, take as many positional images of the asteroid as possible. Here, you're not concerned with quality of image but with obtaining shots containing recognisable field stars and Flora. Open the base shot into a layer-based editor, then add the crossing images as separate layers on top. Align the stars in these layers with the base layer.



Lighten Opacity: 100%

Fill: 100%

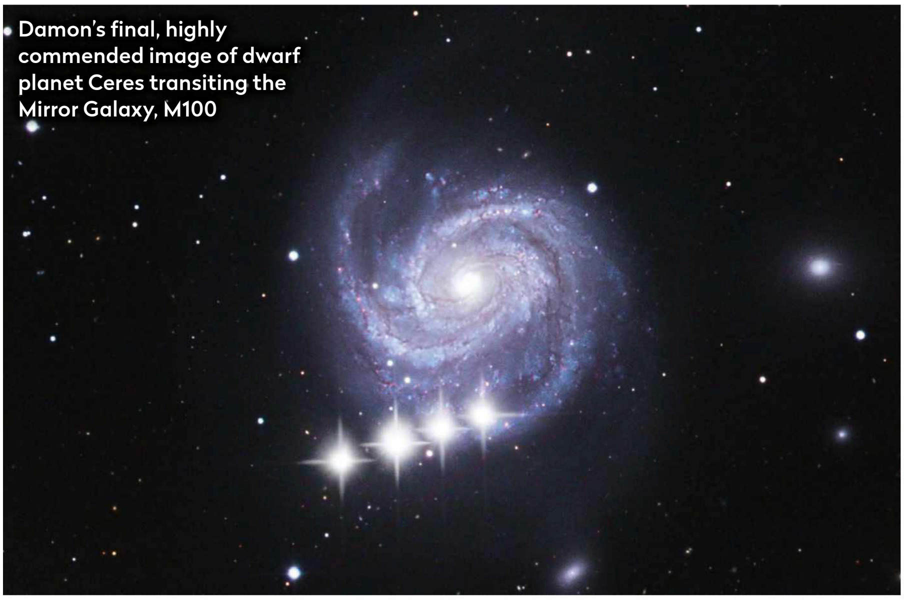
STEP 6

Perform a Levels adjustment on the positional shots so the darker regions darken, and the stars and Flora remain bright. Set upper layers' blend modes to lighten, revealing Flora's path as a sequence of dots moving towards, over and off the Galaxy. Once completed, save, then save as a flattened format such as PNG, adding all capture information onto the finished result.

The Universe in motion

Create the impression of movement in your deep-sky shots

Astronomy Photographer of the Year
Advice from a highly commended entrant in 2024's awards



Damon's final, highly commended image of dwarf planet Ceres transiting the Mirror Galaxy, M100

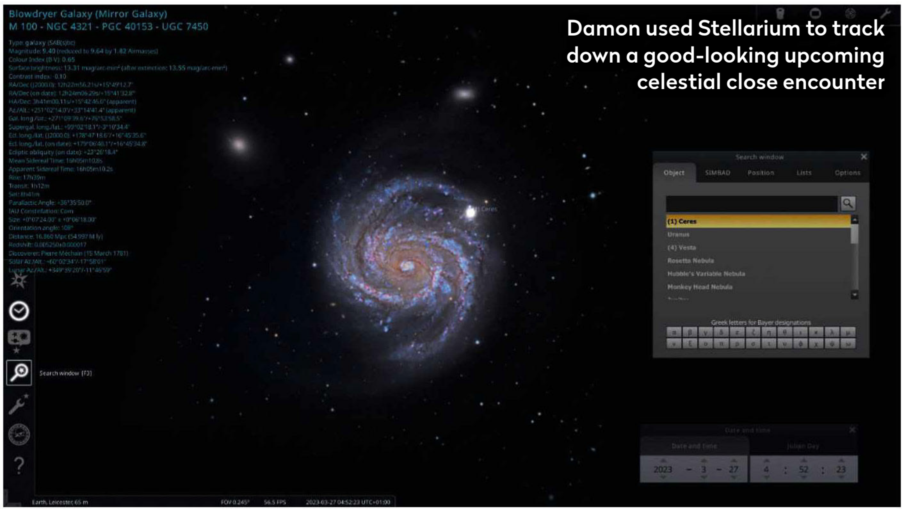
Capturing the Universe in motion is one of the most exciting aspects of astrophotography. It pushes the limits of both your equipment and imagination.

With the help of digital planetarium software, it's possible to prepare for special alignments between celestial objects. This is exactly how I was inspired to capture my image of the dwarf planet Ceres transiting the Mirror Galaxy, M100, that was highly commended in the Planets, Comets and Asteroids category of 2024's APY competition.

Preparation for this sort of image is arguably as important as the processing steps themselves. I used Stellarium to research multiple small celestial objects. Ceres was the most exciting of the bunch, so I changed the date and time in Stellarium day by day and hour by hour to discover Ceres having several close encounters with deep-sky wonders. However, none were as close as its transit of the Mirror Galaxy on 27 March 2023. Eager not to miss out on the upcoming event, I used a remote observatory in Chile, operated by Telescope Live, to gather the data.

To showcase the motion of Ceres across the Mirror's spiralling arms, I took three-minute exposures continuously for eight hours. If I simply stacked all those images, Ceres would appear as a white streak. Instead, I selected four individual frames, spaced out evenly as Ceres moved past the galaxy (see Screenshot 1). Although the transit was obvious, I felt that the background Mirror Galaxy details could be improved, so I took another 18 hours of images via Telescope Live, without Ceres present. These were captured through luminance, red, green and blue filters, and I stacked these separately in PixInsight.

Before adding the four Ceres frames, I cleaned up the image using powerful tools in PixInsight: RC Astro's BlurXTerminator and NoiseXTerminator (see Screenshot 2). BlurXTerminator helps to remove the distortion caused by our

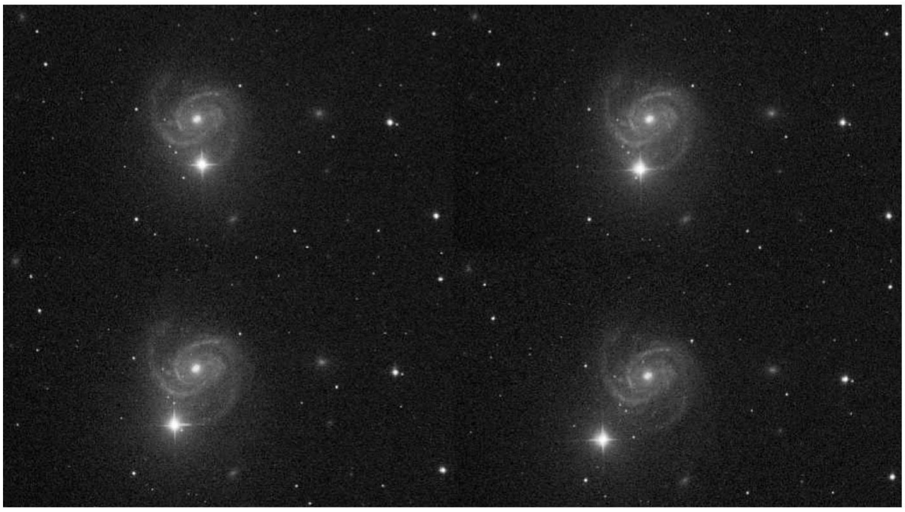


Blowdryer Galaxy (Mirror Galaxy)
M 100 - NGC 4321 - PGC 40153 - UGC 7450

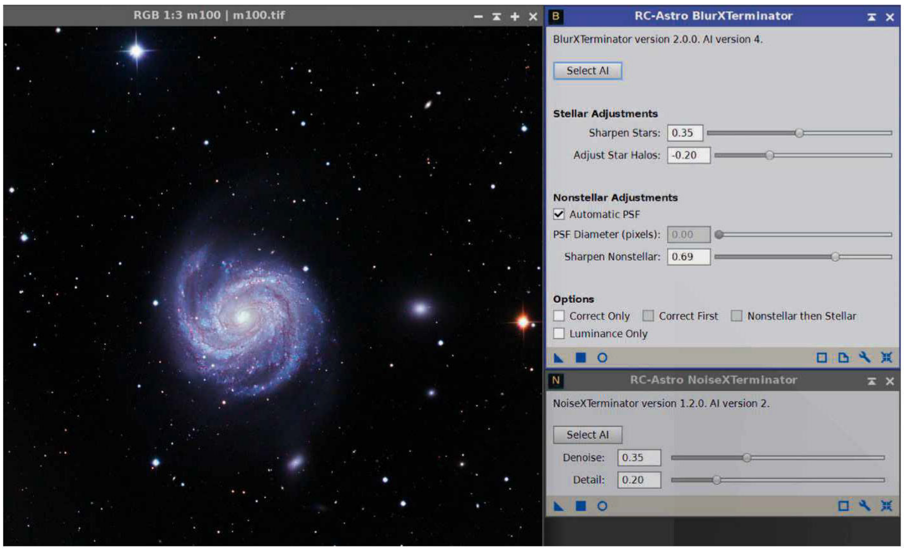
Ceres
Search window [F3]
Search window
Object
SIMBAD
Position
Lists
Options
(1) Ceres
Uranus
(4) Vesta
Rosetta Nebula
Hubble's Variable Nebula
Monkey Head Nebula
Greek letters for Bayer designations
Date and time
Julian Day
2023 - 3 - 27
4 : 52 : 23
Earth, Leicester, 65 m
FOV 0.245°
56.5 FPS
2023-03-27 04:52:23 UTC+01:00

Damon used Stellarium to track down a good-looking upcoming celestial close encounter

ALL PICTURES: DAMON SCOTTING



▲ Screenshot 1: the four three-minute exposures Damon chose to show the movement of Ceres across M100, taken at 02:34, 04:05, 05:38 and 07:06. Ceres was imaged almost entirely in the luminance filter. When trying to stack images of a moving object, stick to one filter to prevent the moving object appearing as a different colour throughout



RGB 1:3 m100 | m100.tif

RC-Astro BlurXTerminator

BlurXTerminator version 2.0.0. AI version 4.

Stellar Adjustments

Sharpen Stars: 0.35

Adjust Star Halos: -0.20

Nonstellar Adjustments

☑ Automatic PSF

PSF Diameter (pixels): 0.00

Sharpen Nonstellar: 0.69

Options

☐ Correct Only ☐ Correct First ☐ Nonstellar then Stellar

☐ Luminance Only

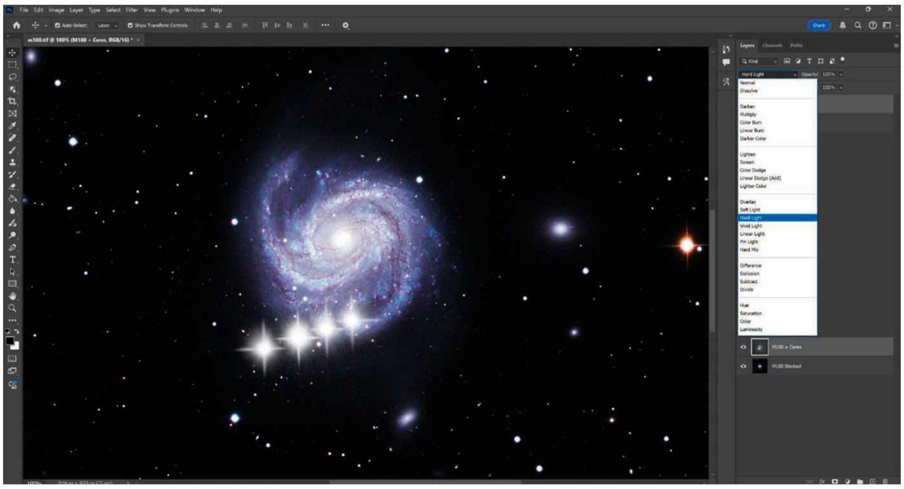
RC-Astro NoiseXTerminator

NoiseXTerminator version 1.2.0. AI version 2.

Denoise: 0.35

Detail: 0.20

▲ Screenshot 2: PixInsight editing tools BlurX and NoiseX work wonders for increasing the clarity of your image, reducing the noise and distortion caused by Earth's atmosphere



▲ Screenshot 3: Photoshop's blending modes give you a variety of methods for combining your images together. The Screen effect was used to combine the four images of Ceres and the Hard Light effect was used to combine that image with the final stacked shot of M100

3 QUICK TIPS

1. Try different Photoshop blending modes to see which works best.

2. Blend the images of the transiting object separately before adding to the stacked image.

3. Enhance the brightness/contrast of the images with the moving object to create a sharp distinction from the background object.

atmosphere. There are three sliders to adjust: Sharpen Stars, Adjust Star Halos and Sharpen Nonstellar.

I increased Sharpen Stars, which reduces star diameter, then decreased Adjust Star Halos to also make them pinpoints. I moved the Sharpen Nonstellar slider quite far to the right, to make the galaxy's appearance razor-sharp.

The NoiseXTerminator tool is even simpler, allowing you to adjust the denoising and detail of your shot. The 'Denoise' slider is in part undoing a lot of the sharpening you have just applied with the BlurXTerminator, so the key here is to find a balance in which the image looks clean but isn't too soft. This can be ensured by also making use of the Detail slider, also in the NoiseXTerminator tool.

Once I was happy with the base image of the Mirror Galaxy, it was time to overlay the Ceres transit by combining each of the four three-minute exposure images with my 18-hour stacked image of M100. In Photoshop, I selected my galaxy and Ceres images, so that they were side by side. I overlaid the four Ceres images by navigating to each window in turn, copying them (Ctrl + A, followed by Ctrl + C) and then pasting them onto the processed Mirror Galaxy image (Ctrl + V). To merge each Ceres image onto the Mirror Galaxy, I used Hard Light blending mode, under Layers (see Screenshot 3). I find this preserved the fine details of the galaxy without the noisy Ceres frames diminishing the image's quality.

My final image (opposite) shows the four images of Ceres blended seamlessly onto the background Mirror Galaxy.

Damon Scotting is a science teacher, YouTuber and award-winning astrophotographer

Your best photos submitted to the magazine this month

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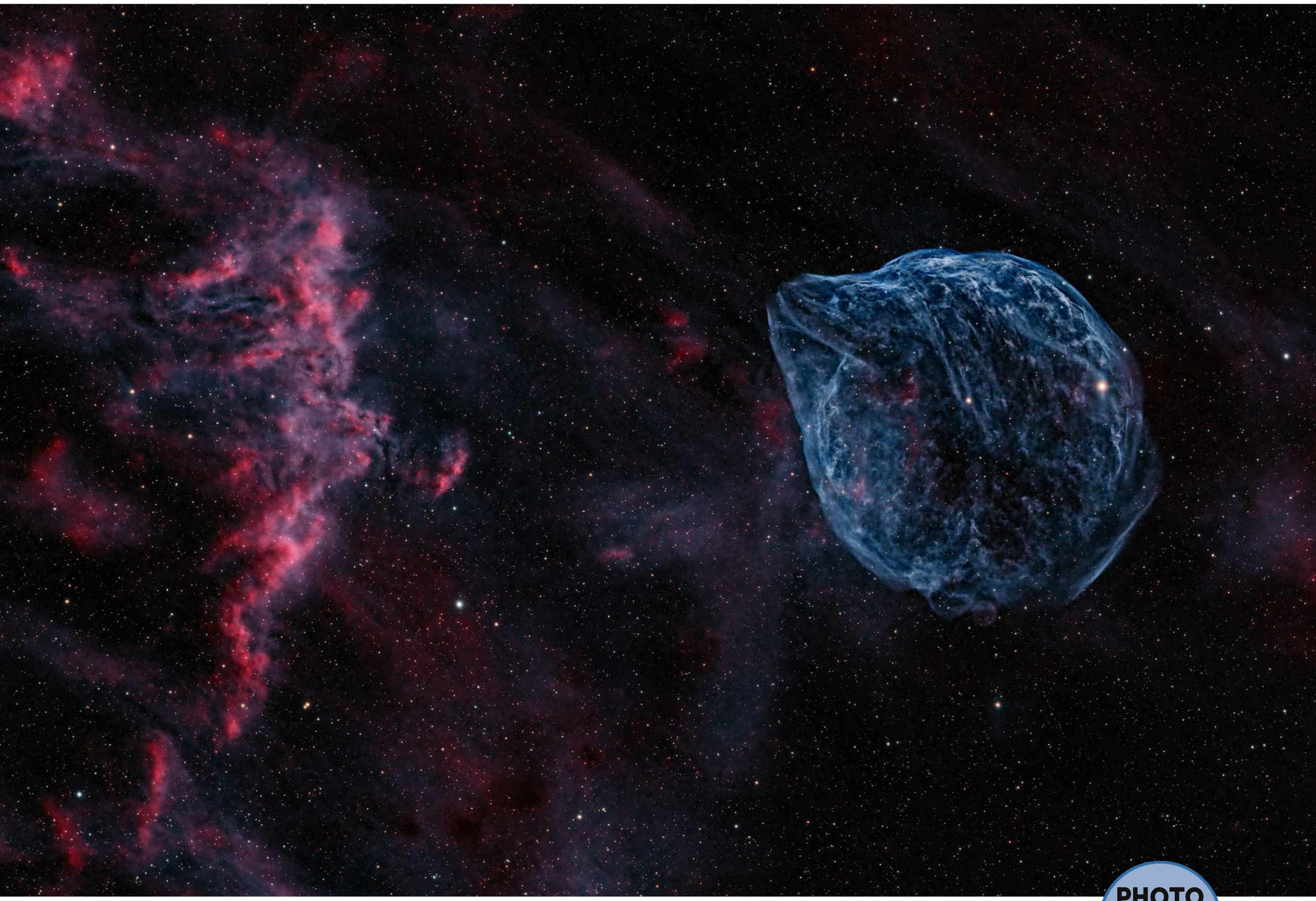


PHOTO OF THE MONTH

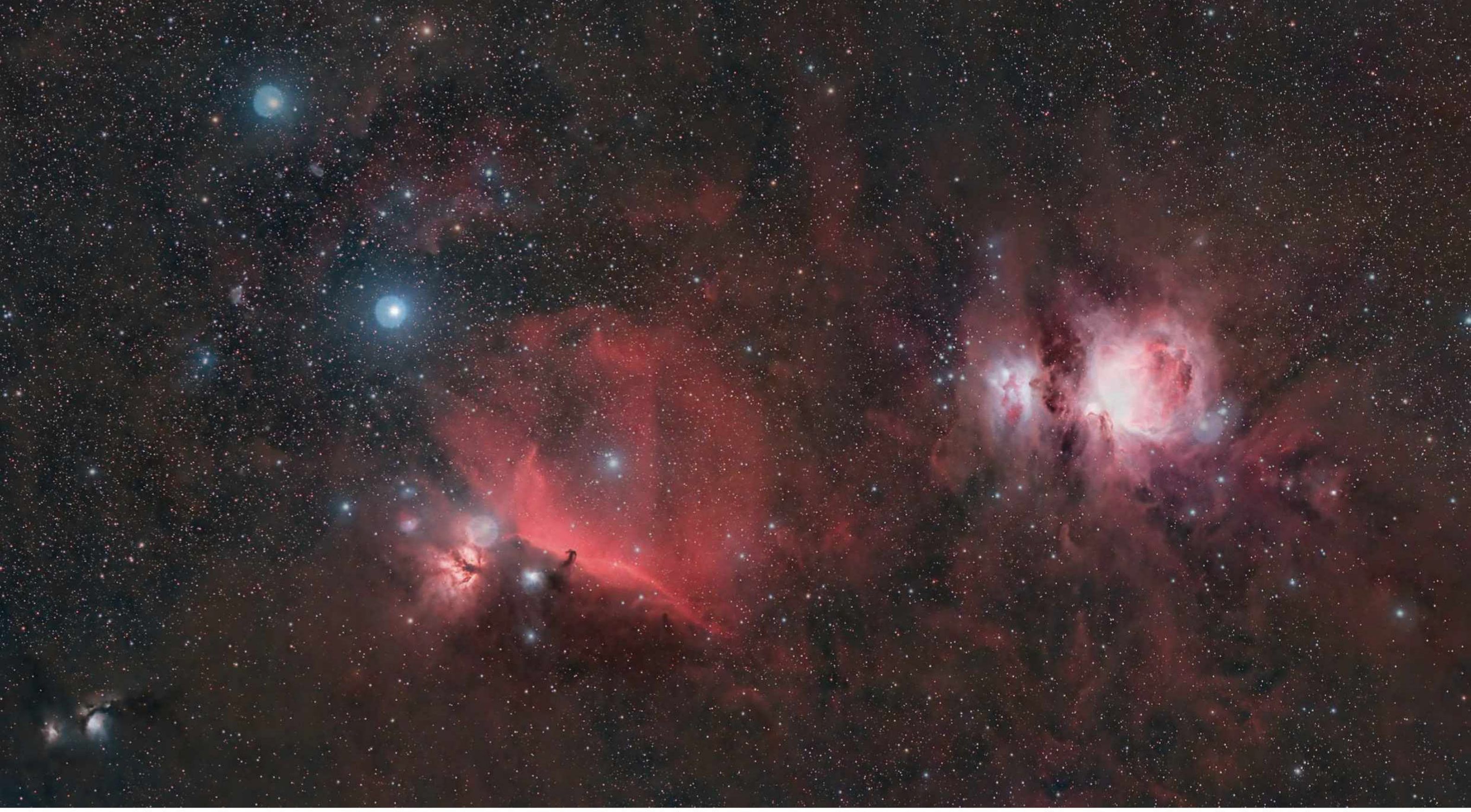
△ The Dolphin Head Nebula

Djaffar Ould Abdeslam, Lozere, France, 29–31 December 2024

Djaffar says: "This was a challenging target due to its faint luminosity and low position, just 20° above the horizon. That heightened the difficulties caused by denser atmospheric layers and increased turbulence, and reduced the window of visibility. I was very pleased to achieve this result over three nights."

Equipment: ZWO ASI2600MM camera, Askar FRA500 refractor, Sky-Watcher EQ6-R mount
Exposure: Ha 24x 600", OIII 53x 600"
Software: NINA, PixInsight

Djaffar's top tips: "Faint objects near the horizon require long exposure times and careful polar alignment. Using narrowband filters to capture the Ha and OIII wavelengths is essential if you want to reveal fine details. A focal length of 250–400mm (this image was 350mm) should provide enough detail while also capturing the surrounding nebulosity. Be ready to spend time in post processing to bring out a nebula's fainter structures. Patience and persistence are key!"

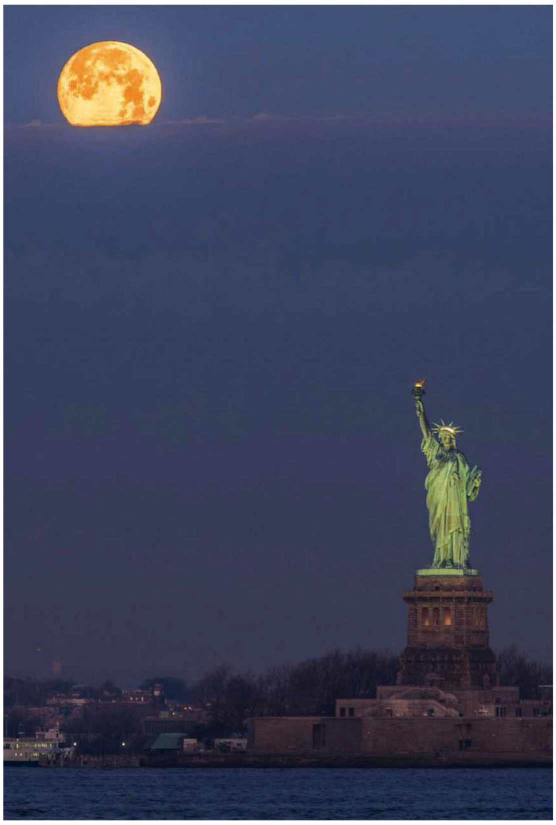


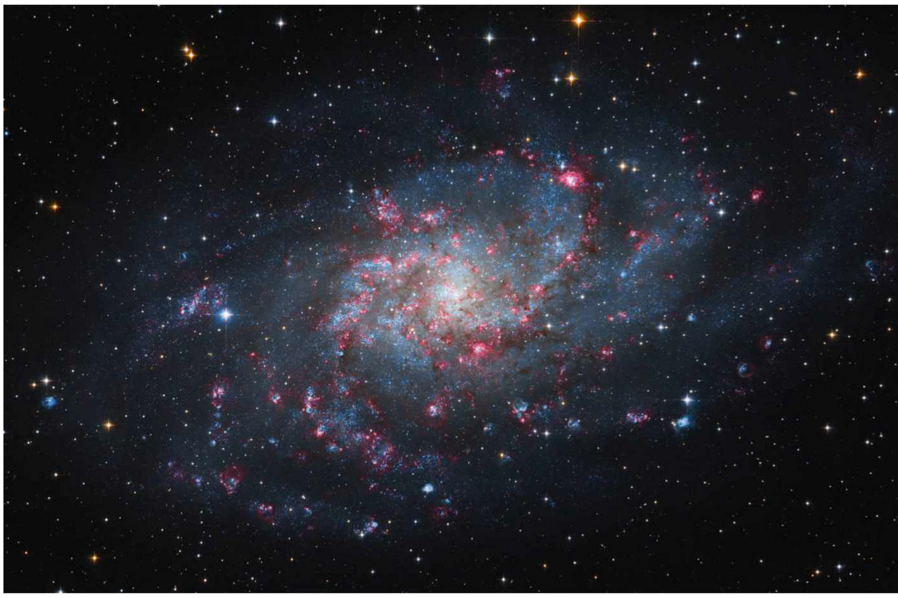
△ Orion's Belt and Sword

Tracey Harty, Penrhyn Bay, Conwy, 31 January 2025

Tracey says: "Testing my new widefield setup in poor conditions, I wasn't optimistic about capturing this region successfully, but the results were far better than I expected!"

Equipment: ZWO ASI071MC Pro camera, Samyang 135mm f/2 lens, Sky-Watcher HEQ5 Pro mount
Exposure: 40x 3', total 2h
Software: DeepSkyStacker, PixInsight, Lightroom





△ The Triangulum Galaxy

Mauro Pea, Meire Bigorie, Piedmont, Italy, 30 November 2024–3 January 2025

Mauro says: "This picture of M33 is the result of six nights of data capture and hundreds of kilometres of driving out under the dark skies of the Italian mountains."

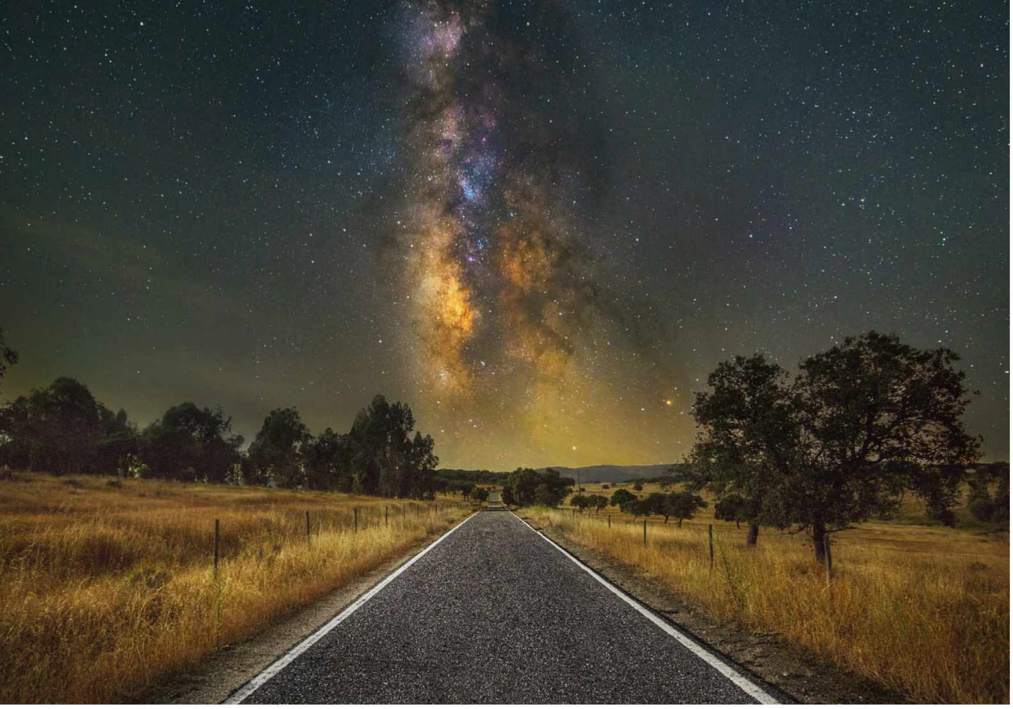
Equipment: ZWO ASI2600MC camera, Tecnosky Carbon 200/800 reflector, iOptron GEM45 mount **Exposure:** RGB 216x 300", Hα/OIII 54x 600" **Software:** PixInsight, Photoshop

◁ Wolf Moon over the Statue of Liberty

Chirag Upreti, New York, USA, 13 January 2025

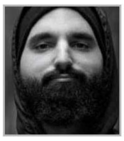
Chirag says: "This image captures the Wolf Moon against a crisp, chilly early morning sky. I was captivated by the way the Moon seemed to surf along the low-lying clouds."

Equipment: Sony α7R IIII camera, Sony 200–600mm lens, Leofoto Ranger LS-255CEX tripod
Exposure: ISO 160 f/9, 1/15" **Software:** Lightroom, Photoshop



◁ Milky Way over Portugal

Rui Santos, Vila Velha de Ródão, Portugal, 11 June 2024



Rui says: "I've always dreamed of capturing Portugal's country roads intertwined with the vastness of the cosmos. There's something about these golden fields that feels timeless."

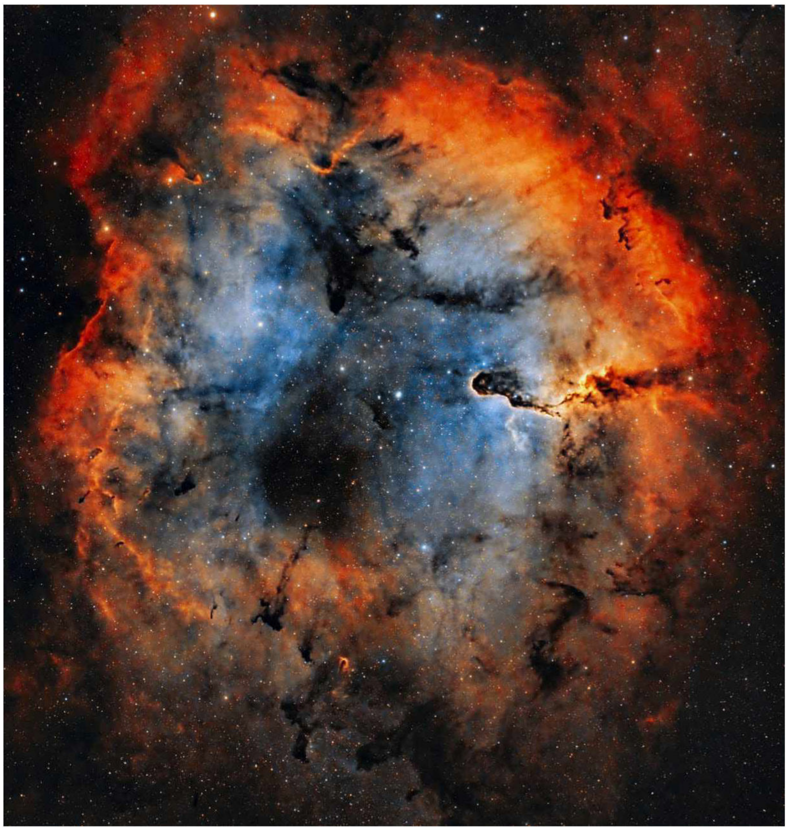
Equipment: Sony A6000 camera, Samyang 12mm lens, Geekoto AT24Pro Dreamer tripod
Exposure: Sky ISO 800 f/4, 4x 100"; foreground ISO 6400 f/2.8, 5x 20"
Software: Luminar, Sequator, Photoshop

The Elephant's Trunk Nebula ▷

Adriano Anfuso, Wëntger, Luxembourg, 6 October 2024

Adriano says: "The Elephant's Trunk seemed a natural target to image from my Bortle 4 location. I wasn't sure if just over six hours of exposure would be enough, but as I was processing the data I could see the result was going to be stunning!"

Equipment: ZWO ASI294MC Pro camera, William Optics RedCat 51 refractor, ZWO AM5 mount
Exposure: 75x 300" **Software:** PixInsight

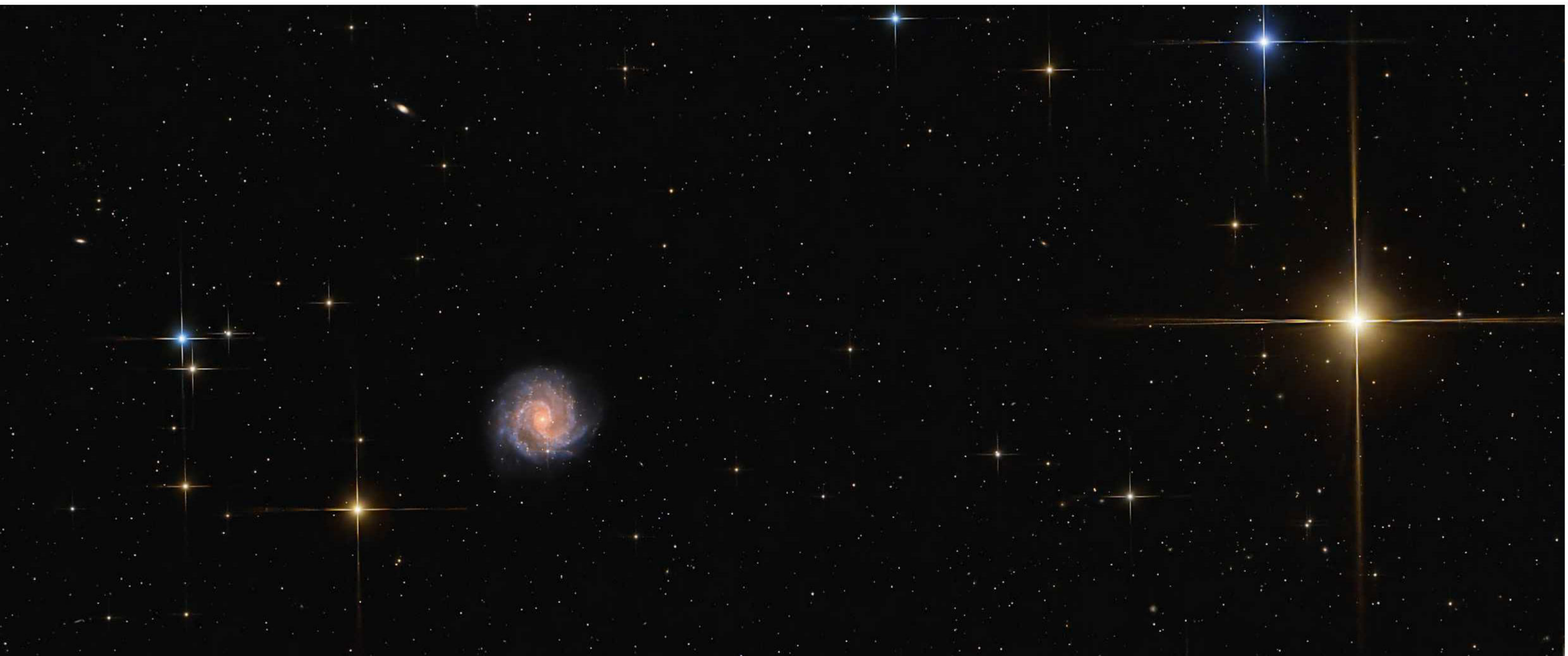


▽ Tania Australis and NGC 3184

David Hugill, Cirencester, Gloucestershire, 9 January 2025

David says: "Star clusters and a galaxy made for a challenging target. Aligning my home-made star-spike mask took a while, and a bright Moon didn't help, but the result was worth the time and effort."

Equipment: ZWO ASI585MC Pro camera, StellaMira 90mm ED refractor, ZWO AM3 mount
Exposure: 375x 60" **Software:** PixInsight

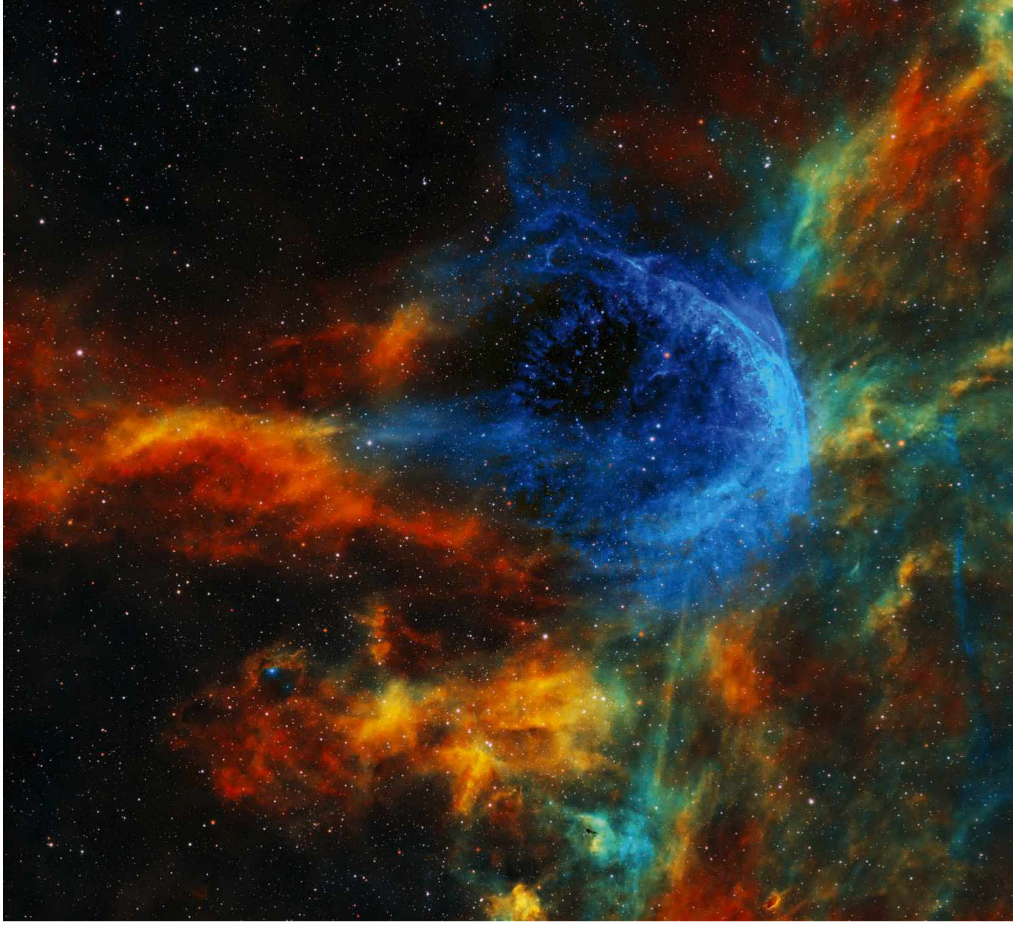


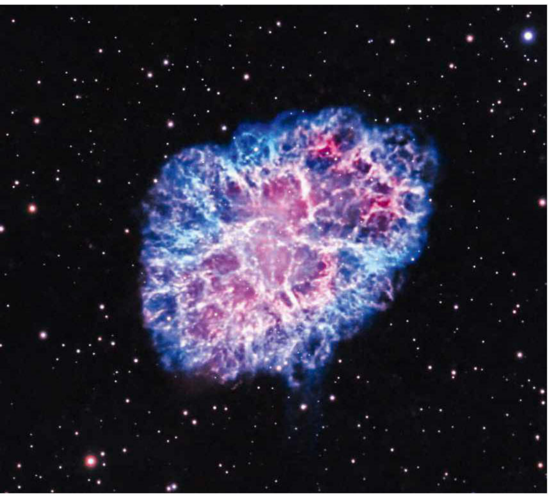
Wolf-Rayet star WR134 ▷

Steve Leonard, Markham, Ontario, Canada, 25 April–27 June 2024

Steve says: "Processing was pushed to the limit in this image of WR134 and its surrounding blue bubble, yielding a fresh take where the bubble appears to be propelled to the right by a fiery thrust."

Equipment: ZWO ASI1600MM Pro camera, Astro-Tech AT115EDT refractor, Sky-Watcher EQ6-R mount
Exposure: RGB 30" each, OIII 10h, Ha 8h, SII 6h
Software: PixInsight, Topaz Denoise





◁ The Crab Nebula

Mohammed Dawoud, Al Kharrara desert, Qatar, 26 December 2024

Mohammed says: "I've wanted to capture this beautiful nebula for a couple of years. It needs accurate focusing, good seeing and long exposure times, but I'm happy with how it turned out."

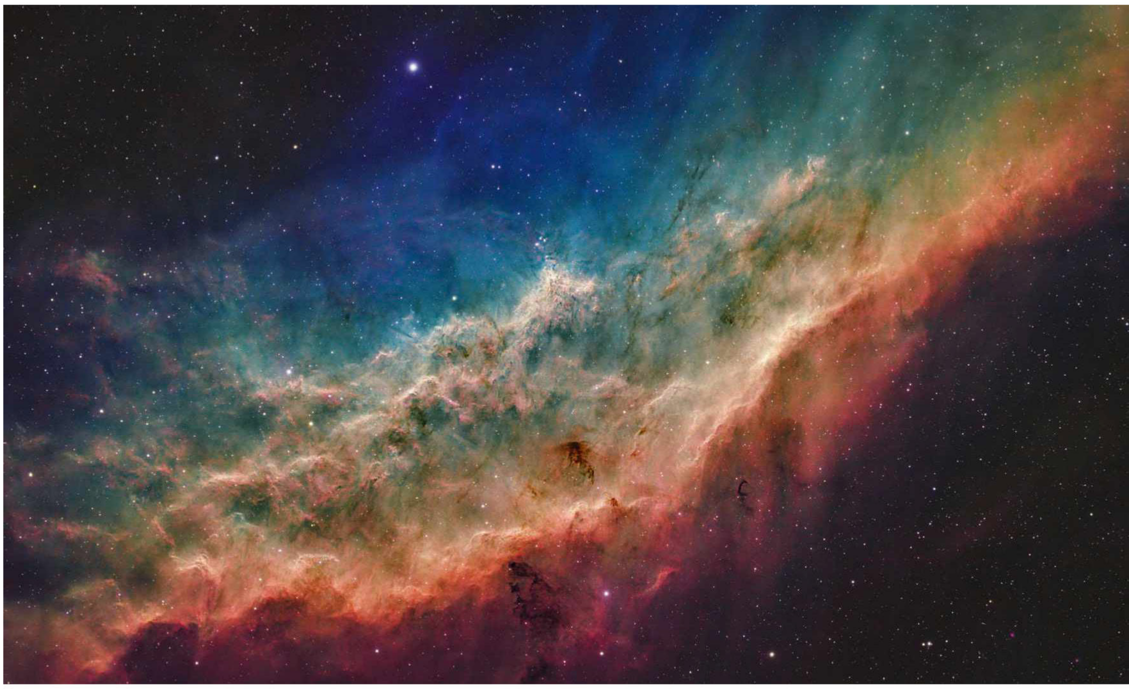
Equipment: ZWO ASI1600MM camera, Celestron EdgeHD 8-inch Schmidt–Cassegrain, iOptron GEM45 mount **Exposure:** Ha 49x 600", OIII 39x 600", SII 35x 600" **Software:** Astro Pixel Processor, PixInsight, Photoshop

The California Nebula ▷

Kasra Karimi, Bungay, Suffolk, 2–4 January 2025

Kasra says: "This was an attempt to take a true Hubble Palette SHO photo using a one-shot colour camera and two sets of dual-band filters."

Equipment: ZWO ASI6200MC Pro camera, Askar 103 APO refractor, ZWO AM5N mount
Exposure: Ha and OIII 65x 300", SII and H-beta 124x 300"
Software: PixInsight, Photoshop



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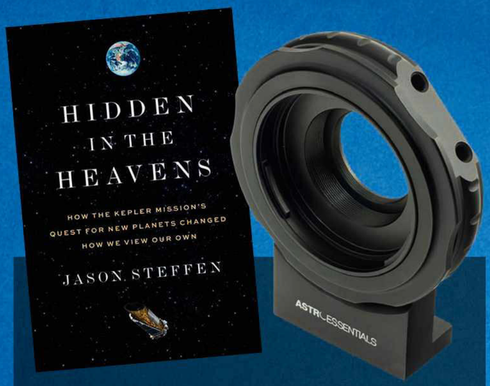
Telephoto
Wide-Angle
DWARF LAB

86

DwarfLab's tiny Dwarf II smart scope was a portability game-changer. So what does our reviewer make of the new Dwarf 3? Read on to find out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HOW THE KEPLER MISSION'S QUEST FOR NEW PLANETS CHANGED HOW WE VIEW OUR OWN
JASON STEFFEN
ASTRO ESSENTIALS

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HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★☆ Very good
★★★☆☆ Good ★★☆☆☆ Average ★☆☆☆☆ Poor/avoid

Our experts review the latest kit

FIRST LIGHT

DwarfLab
Dwarf 3 smart telescope

The ultra-portable dual-lens scope has had an upgrade – and we're impressed

WORDS: SONIA TURKINGTON

VITAL STATS

- **Price** £519 (£492 via DwarfLab)
- **Optics** Wide-angle and telephoto lenses
- **Aperture** 35mm
- **Focal length** 150mm
- **Equivalent focal length** 737mm (tele), 45mm (wide)
- **Sensor** Sony IMX678 Starvis 2
- **Power:** Built-in 10,000mAH battery
- **Storage** 128GB eMMC
- **Ports** USB-C
- **App control** DwarfLab app
- **Connectivity** Wi-Fi, near field (NFC) one-touch
- **Weight** 1.3kg
- **Extras** 2x magnetic solar filters, USB-C cable, wipe cloth, carry bag
- **Supplier** DwarfLab
- **Email** support@dwarflab.com
- **www.dwarflab.com**

Smart telescopes have been taking the market by storm, with DwarfLab's Dwarf II originally standing out due to its portability. Now DwarfLab is back with the Dwarf 3, which features a larger aperture, longer focal length and greater storage capabilities, in addition to new shooting modes, internal filters and functions. We were keen to see what it could do.

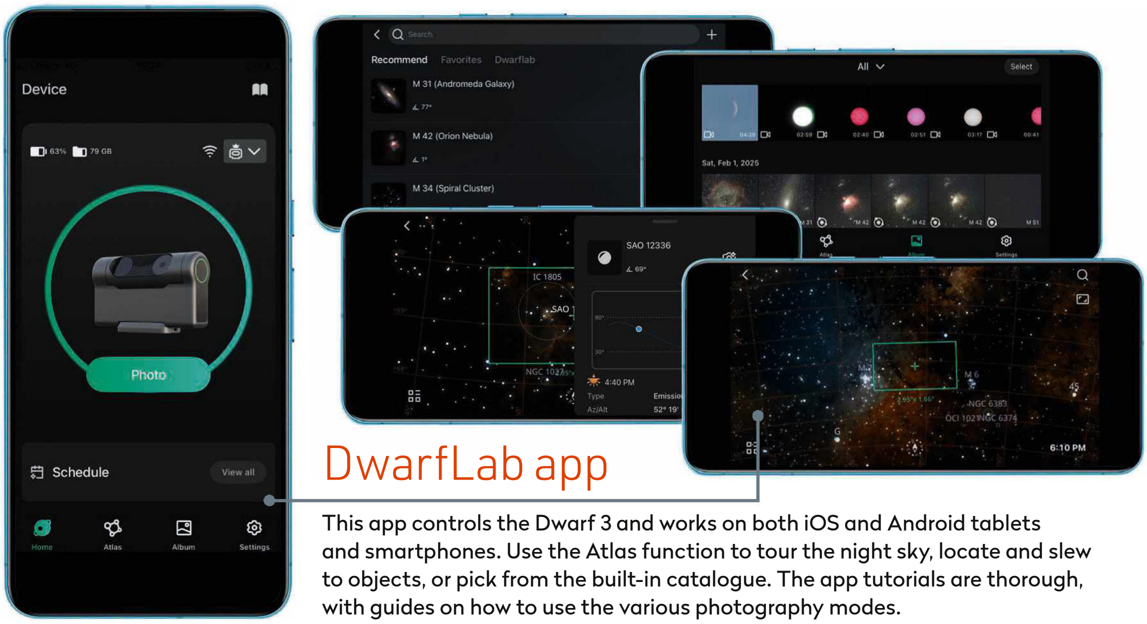
The Dwarf 3 once again came well packaged in a box with a carrying bag that snugly houses the unit and accessories. However, unlike its predecessor, this time it doesn't include a tripod as standard but attaches to any photography tripod with a standard ¼-inch screw.

Pairing the unit with the DwarfLab app is easily achieved: just open the app to connect via the device's Wi-Fi network. Much like the Dwarf II, the Dwarf 3 comes with solar filters, so we popped these on and first turned to the Sun. We tilted the telescope to roughly align it with our target, before starting the Sun Track mode. We were able to adjust our capture settings, including the shutter speed, gain and live stacking within the app, seeing lovely sunspot details even via the autofocus.

Over a clear night, we headed out for dark-sky testing, starting with a well-illuminated Moon. Again, we found the process of centring the Moon in-frame using the app's joystick function beautifully simple, before selecting Moon Track. Establishing the best settings was easy thanks to the excellent live view in the app; the autofocus worked well, as did the default settings (although these can all be tweaked in Astro mode). Setting the Dwarf 3 to live stack, we enabled the AI noise-reduction tool. While the Moon appeared small in the frame, we were able to crop quite close in post-processing without losing details.

No lens dew

You cannot adjust the focus on the wide-angle lens, and while we thought the focus was excellent for daytime use, we did feel the starscapes were slightly out of focus. Because we were outside Milky Way ▶



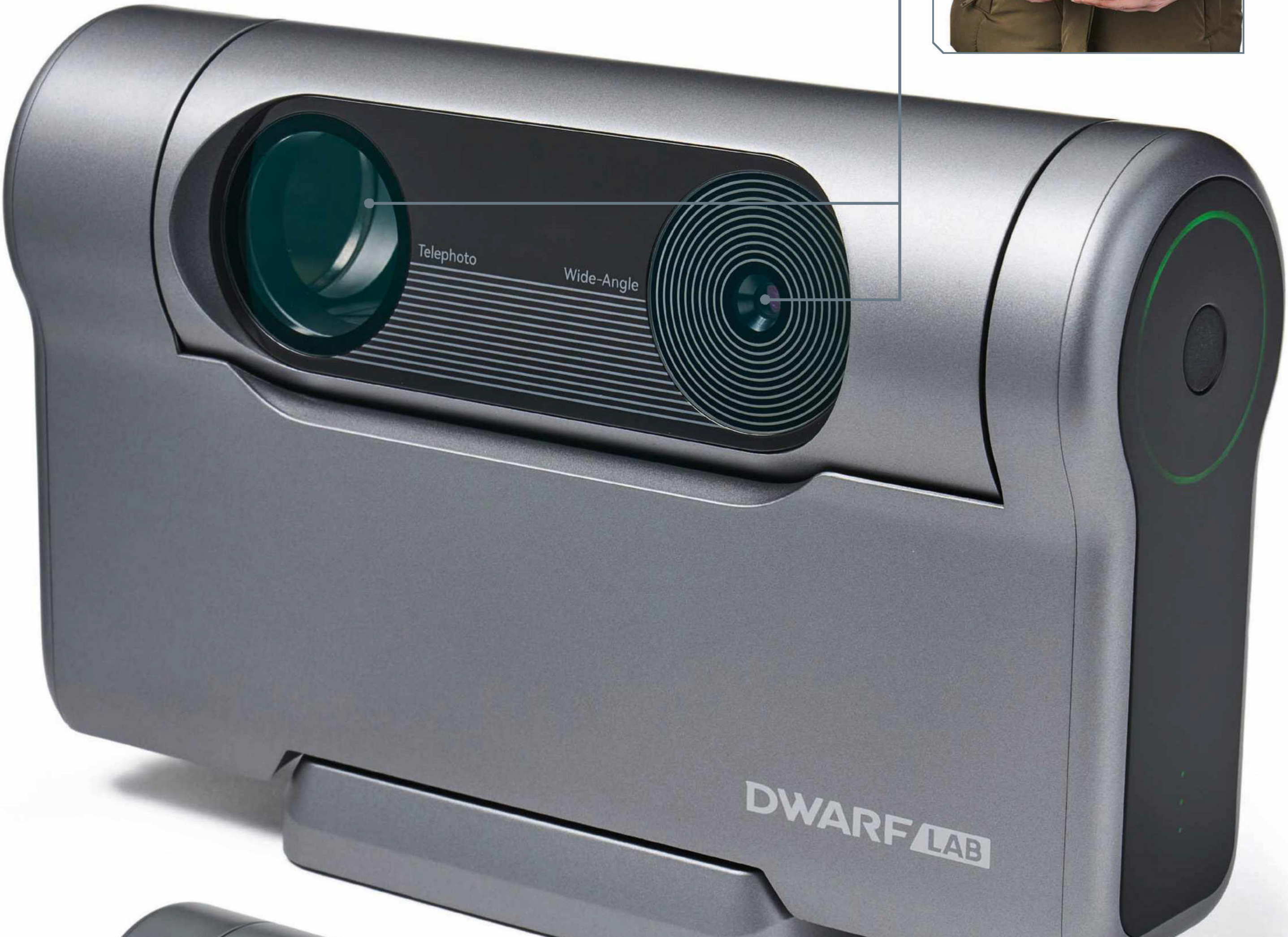
DwarfLab app

This app controls the Dwarf 3 and works on both iOS and Android tablets and smartphones. Use the Atlas function to tour the night sky, locate and slew to objects, or pick from the built-in catalogue. The app tutorials are thorough, with guides on how to use the various photography modes.

@THESHED/PHOTOSTUDIO X 3, DWARFLAB.COM X 5

Telephoto and wide-angle lenses

The Dwarf 3 features a dual-lens system. The wide-angle lens has a 45° field of view and can be used for daytime imaging and videos, timelapses and nightscapes. Combined with the telephoto lens, the Dwarf 3 captures a range of photos, from daytime nature snaps to Milky Way vistas and in-depth nebulae images.



Internal filters

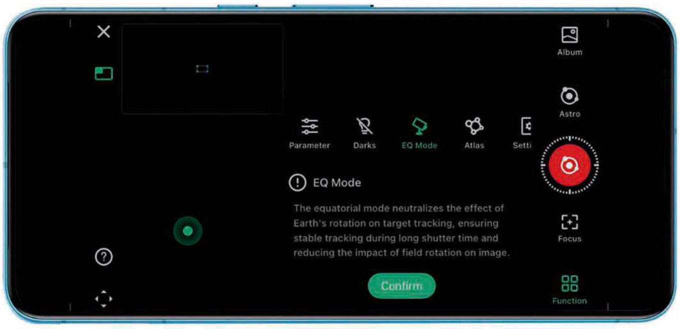
The Dwarf 3 arrives with built-in filters, so through the telephoto lens you can switch between visual, astro and dual-band options. The visual filter is great for daytime photography and lunar and solar imaging, while the astro filter is used for night-sky objects. The dual-band filter is an excellent new addition for nebulae.

New EQ mode

Throughout our time with the Dwarf 3, the Go-To function performed consistently well, centring our deep-sky target of choice each time. Object tracking was also easily enabled via the Telephoto live view mode.

However, a key difference between the Dwarf 3 and its predecessor is the introduction of an equatorial (EQ) mode, an essential component for deep-sky photography because it reduces the field rotation seen via altaz mounts and boosts the maximum exposure time. We get some EQ mount capabilities for exposures up to 60 seconds, without the expense of a new mount.

It's a slightly strange process to set up, as you must face the back of the Dwarf 3 device northwards and tilt it at the angle of your latitude – a much simpler version of the traditional polar alignment seen with full EQ mounts. While it takes some getting used to, the app provides excellent clear instructions. The stars in our image of Andromeda stayed round and field rotation was greatly reduced compared to images taken with the Dwarf II.


Album
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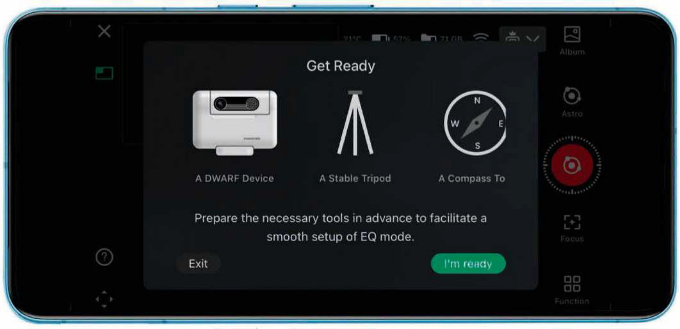
EQ Mode
Atlas
Setti
Focus
Function
Confirm

EQ Mode

The equatorial mode neutralizes the effect of Earth's rotation on target tracking, ensuring stable tracking during long shutter time and reducing the impact of field rotation on image.


Album
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A DWARF Device
A Stable Tripod
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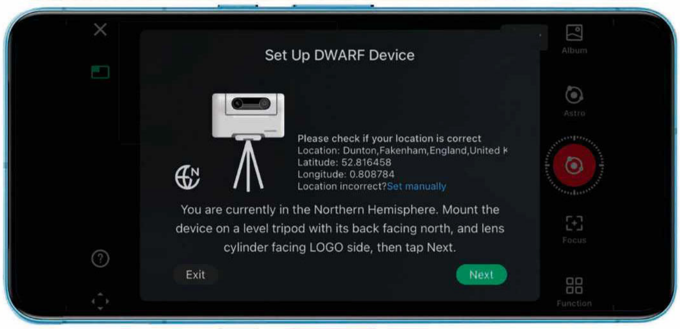
S
Exit
I'm ready

Get Ready

Prepare the necessary tools in advance to facilitate a smooth setup of EQ mode.


Album
Astro
Focus
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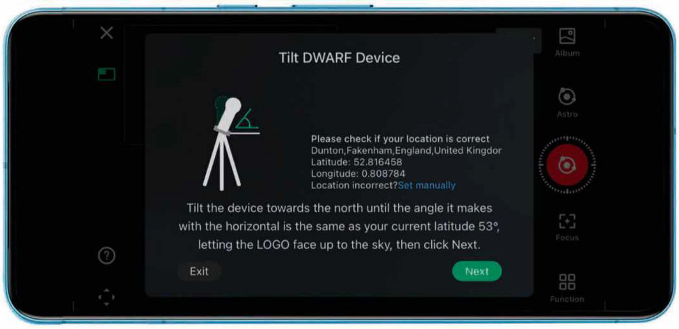
N
Exit
Next

Set Up DWARF Device

Please check if your location is correct
Location: Dunton,Fakenham,England,United K
Latitude: 52.816458
Longitude: 0.808784
Location incorrect?Set manually

You are currently in the Northern Hemisphere. Mount the device on a level tripod with its back facing north, and lens cylinder facing LOGO side, then tap Next.


Album
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Function
Exit
Next

Tilt DWARF Device

Please check if your location is correct
Dunton,Fakenham,England,United Kingdor
Latitude: 52.816458
Longitude: 0.808784
Location incorrect?Set manually

Tilt the device towards the north until the angle it makes with the horizontal is the same as your current latitude 53°, letting the LOGO face up to the sky, then click Next.

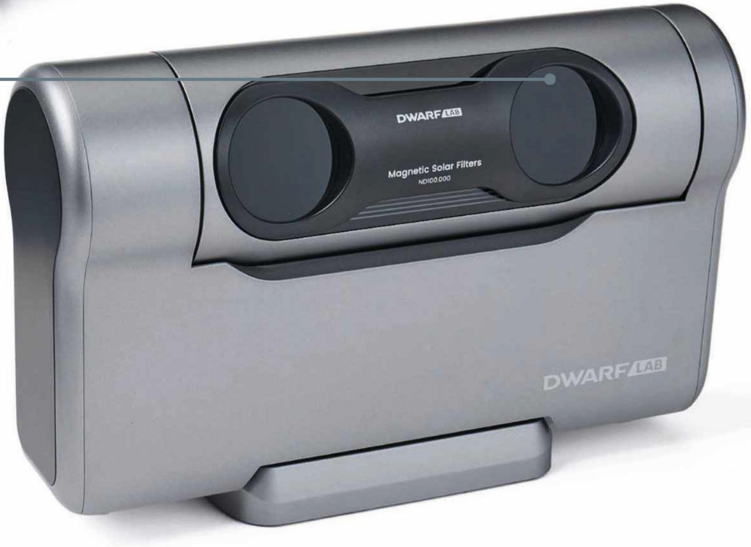
Carry case

The Dwarf 3 arrives with a plush carry case and shoulder strap, meaning you can easily take it anywhere with you. The attention to detail is excellent. We loved the tripod straps on the bottom, meaning you could fix a tripod onto the bag, plus one side has backpack straps.

Clip-on filters

The Dwarf 3 comes with magnetic solar filters in a handy 'sunglasses' bracket that allows easy attachment to the lenses. These instantly turn it into a solar-imaging device, so you can safely image solar activity such as sunspots. We also caught a glimpse of surface detail in our images.

DWARF LAB
Magnetic Solar Filters
ND100.000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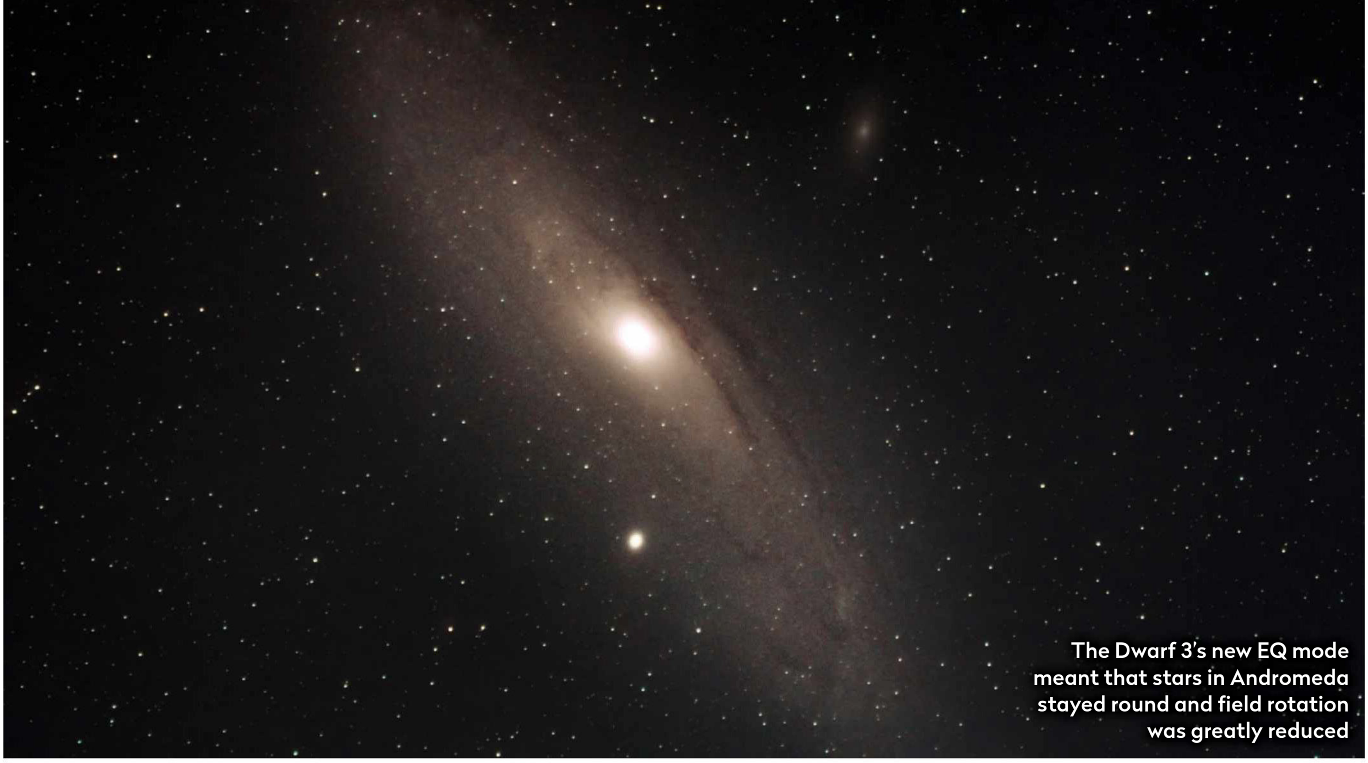
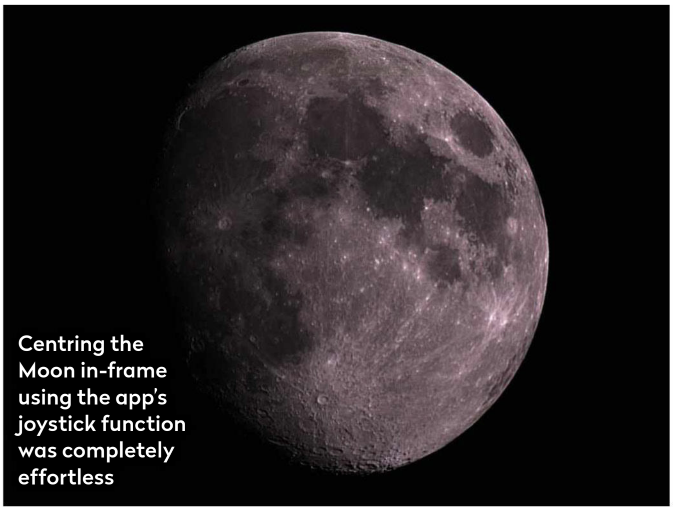
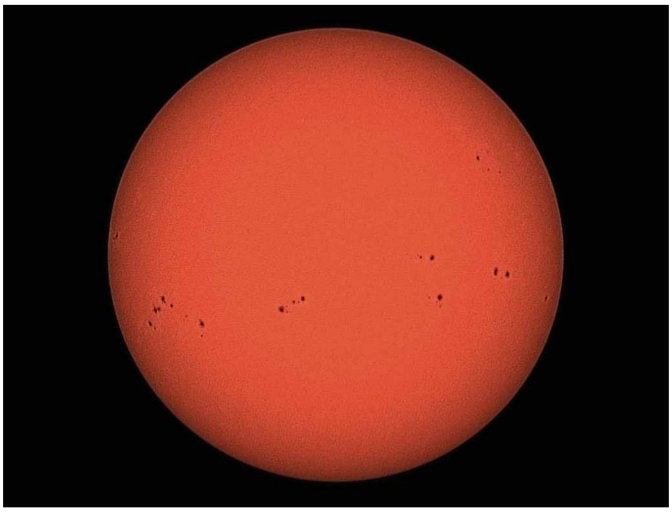


The Dwarf 3's new EQ mode meant that stars in Andromeda stayed round and field rotation was greatly reduced



Centring the Moon in-frame using the app's joystick function was completely effortless



▲ Using the included solar filters and Sun Track mode, we were able to see some lovely sunspot details

▶ season, this did ensure our attention was firmly on the telephoto lens to take advantage of some winter deep-sky objects.

We liked the fact that the app prompts you to capture dark frames before imaging – an essential ingredient for reducing image noise. We noted a marked improvement in images that had dark frames added versus those that didn't.

For deep-sky imaging, we opted for the Andromeda Galaxy and the Rosette Nebula, noting that the Dwarf 3 tracked consistently well throughout our sessions. We did note the slightest hint of star coma when we zoomed in later. Andromeda was imaged using the new EQ mode for longer exposures, but for short exposures we were able to put the Dwarf 3 down, select a target and let the device plate-solve before performing accurate Go-To.

During extremely cold nights, we were impressed by the internal battery performance in comparison to other smart telescopes. In near-zero temperatures, a full charge lasted us over four hours, and it didn't take long to recharge.

We were amazed that, despite damp nights, we saw next to no dew on the lenses. While the Dwarf 3 does not have internal heaters, its battery appears to keep the unit warm enough to ward moisture off (though perhaps at the expense of a little image noise).

We were left impressed by this little budget smart telescope. A lot of thought has gone into the standard accessories, from the galaxy-friendly 'astro filter' to the dual-band filter for emission nebulae. The Sun and Moon details are pleasing for a small aperture, providing lovely sunspot and crater details. Overall, we felt the image quality was a step up from the Dwarf II, while the extra focal length was welcomed for all popular targets.

With a little post-processing and patience, the Dwarf 3 will reward any astronomer, regardless of experience. The range of imaging modes and filters ensures this handy smart telescope is both fun and a worthy device for all astrophotographers.

VERDICT

Build & design	★★★★☆
Ease of use	★★★★☆
Features	★★★★☆
Go-To accuracy	★★★★☆
Imaging quality	★★★★☆
OVERALL	★★★★☆

KIT TO ADD

1. Photographic tripod

2. Ballhead

3. USB-C power adaptor

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Our experts review the latest kit

FIRST LIGHT

Acuter Voyager MAK80-Fast telescope set

A compact all-rounder that's remarkably capable for its pint-sized price

WORDS: MARY MCINTYRE

VITAL STATS

- **Price** £199
- **Design** Maksutov–Cassegrain
- **Optics** 80mm primary mirror
- **Focal length** 850mm, f/10.6
- **Focuser** Friction-drive
- **Mount** 45mm Vixen/Sky-Watcher dovetail bar, ¼-inch tripod thread
- **Extras** Diagonal, 12.5mm and 20mm eyepieces, 6x21mm finderscope, smartphone adaptor, carry case
- **Weight** 1.5kg (OTA)
- **Supplier** Optical Vision Ltd
- **Email** info@opticalvision.co.uk
- **www.**opticalvision.co.uk

Maksutov–Cassegrain telescopes are 'catadioptric' instruments that are particularly compact because the light path from the primary mirror is 'folded' by the secondary mirror, meaning they pack a long focal length into a short tube. Their corrector plates, placed at the front, correct coma and chromatic aberrations. We tested Acuter's latest lightweight model, the Voyager MAK80-Fast, which boasts a respectable 850mm focal length. It takes over from its predecessor, the MAK80, with a new patent-pending friction-drive focuser, a longer focal length and two wide-angle eyepieces with 70° apparent field of view.

The telescope arrived inside a padded case in a gift box, complete with accessories including finderscope, diagonal, eyepieces and a smartphone adaptor. Setting up was quick and easy, and although most of the parts are made from plastic that marks easily, we thought it was well-built.

The telescope is fitted with a dovetail bar so it can be mounted on astronomical mounts, but also has three 1/4-inch camera screw holes to mount onto standard photography tripods.

'Fast' in the Voyager's name doesn't refer to the conventional use relating to the light-gathering capability of the optics. In this case, it refers to a patent-pending focusing system that comes with a sliding scale to help the user quickly find the point of focus for objects located at different distances. For astronomical use, everything is focused near to infinity and you'll struggle to see the scale in the dark.

The focal ratio of f/10.6 would be considered as quite a slow telescope, but visually it performed well on a variety of different objects. After allowing the telescope to cool outside for 30 minutes, we mounted it onto a camera tripod and pointed at the Moon.

Beautifully pin-sharp stars

The lunar features were sharp with good contrast and it was comfortable to observe with no excessive glare. There was some chromatic aberration on the very edges of the field of view but nothing that spoiled the experience. We then pointed at the ▶

Exciting optics

The Acuter Voyager MAK80-Fast packs its 850mm focal length into a tube that is just 29cm long without the diagonal. The stars were pin-sharp and only slight coma aberration was noticeable at the very edges, provided the eye was positioned correctly at the eyepieces.

Being f/10.6, viewing fainter objects required good dark adaptation and averted vision, but the resolution was impressive. When we viewed and created a sketch of the Orion Nebula, the trapezium at the centre was easily resolved and a lot of nebulosity was visible.

Taking a tour through key Messier objects, galaxies and clusters looked particularly lovely, especially with averted vision. When viewing Saturn, the rings were easily resolved despite the altitude and ring tilt not being favourable, and Saturn's moon Titan was just visible.

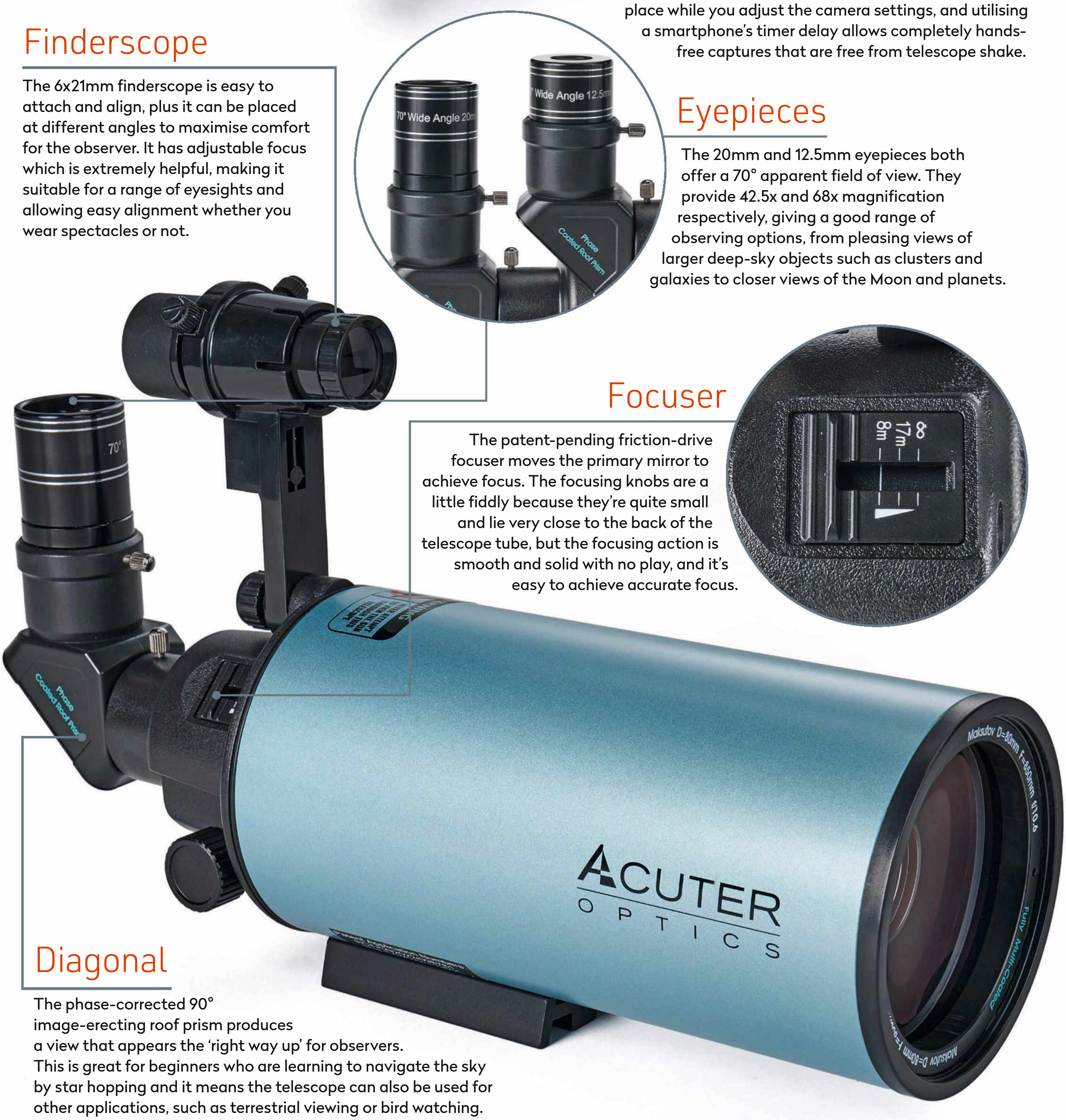
Moving over to Jupiter, we couldn't quite see the Great Red Spot directly, but we could see the break in the cloud belt either side of it. The optics were undeniably impressive for a telescope at this price point.

Maksutov D=80mm F=850mm f/10.6
Fully Multi-Coated
ACUTER OPTICS

ALL PHOTOS: @THESHED/PHOTOSTUDIO

Smartphone holder

The universal smartphone holder allows the user to perfectly align the phone camera lens then securely attach it above the eyepiece. The phone is held firmly in place while you adjust the camera settings, and utilising a smartphone's timer delay allows completely hands-free captures that are free from telescope shake.



Finderscope

The 6x21mm finderscope is easy to attach and align, plus it can be placed at different angles to maximise comfort for the observer. It has adjustable focus which is extremely helpful, making it suitable for a range of eyesights and allowing easy alignment whether you wear spectacles or not.

Eyepieces

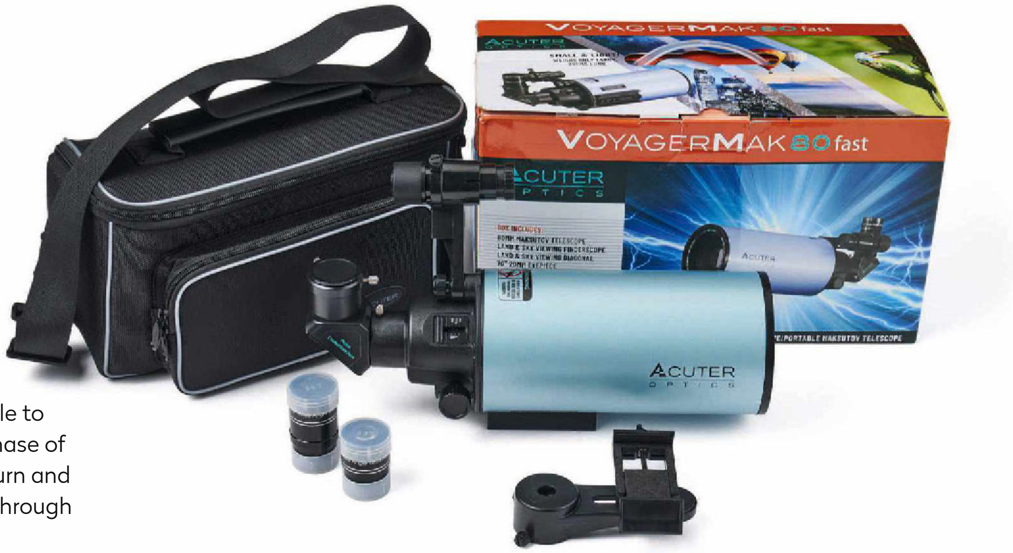
The 20mm and 12.5mm eyepieces both offer a 70° apparent field of view. They provide 42.5x and 68x magnification respectively, giving a good range of observing options, from pleasing views of larger deep-sky objects such as clusters and galaxies to closer views of the Moon and planets.

Focuser

The patent-pending friction-drive focuser moves the primary mirror to achieve focus. The focusing knobs are a little fiddly because they're quite small and lie very close to the back of the telescope tube, but the focusing action is smooth and solid with no play, and it's easy to achieve accurate focus.

Diagonal

The phase-corrected 90° image-erecting roof prism produces a view that appears the 'right way up' for observers. This is great for beginners who are learning to navigate the sky by star hopping and it means the telescope can also be used for other applications, such as terrestrial viewing or bird watching.



KIT TO ADD

1. Acuter Traverse Go-To mount and tripod

2. Sky-Watcher 2x deluxe Barlow lens

3. Sky-Watcher 1.25-inch Moon filter

▶ planets and were able to observe the gibbous phase of Venus, the rings of Saturn and cloud belts on Jupiter through both eyepieces.

After the Moon had set, we mounted the telescope onto a Go-To equatorial mount and focused our sights on deep-sky objects. We observed the Orion Nebula, M42, Andromeda Galaxy, M31, and Pleiades, M45, appreciating beautifully pin-sharp stars. Fainter open clusters such as M35, M36 and M37 were best viewed with the 20mm eyepiece, and the stars showed no signs of coma aberration if the eye was perfectly aligned with the eyepiece.

A few nights later, we tested the universal smartphone holder to take photographs of the Moon via our native camera app. There was a hint of colour fringing along the edge, but the photo was sharp and clear. Longer exposures of faint objects will be possible with other phone photography apps.

We also wanted to test how it performed with other cameras. We attached a budget DSLR camera using a T-ring and 1.25-inch tube fitted to the telescope in place of the diagonal and were able to achieve focus with and without a 2x Barlow. We took photographs of the Orion Nebula and the Moon and got pleasing results.

Finally, we took some videos of the Moon and Jupiter using a budget high-frame-rate CMOS camera and stacked the best frames. Again, the results were pleasing for such an affordable telescope.

The compact size makes the Voyager MAK80-Fast easy to mount and transport. The padded case has a handy carry handle and shoulder strap, and easily fits the complete set inside the two compartments. It would be an excellent first telescope, but a good addition for an experienced observer or astrophotographer who is looking for something easy to take away on holiday. Although small, this petite telescope certainly packs a punch. It's a versatile all-rounder and has the advantage of also being useful for non-astronomy applications.

VERDICT

Build & design	★★★½☆
Ease of use	★★★★☆
Features	★★★★☆
Imaging quality	★★★½☆
Optics	★★★★☆
OVERALL	★★★★☆

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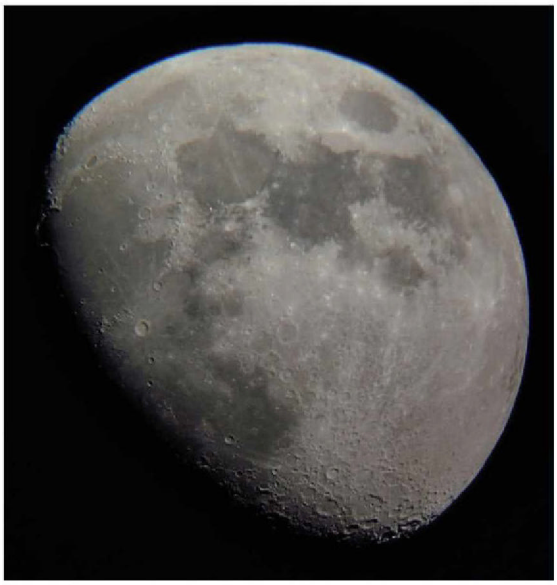
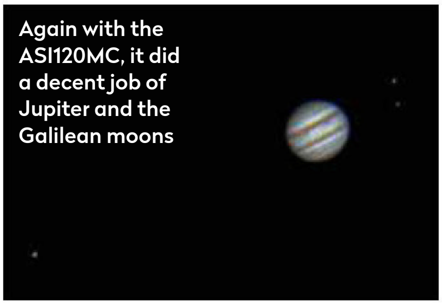
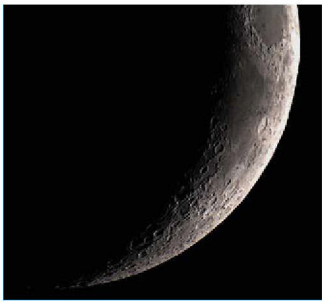


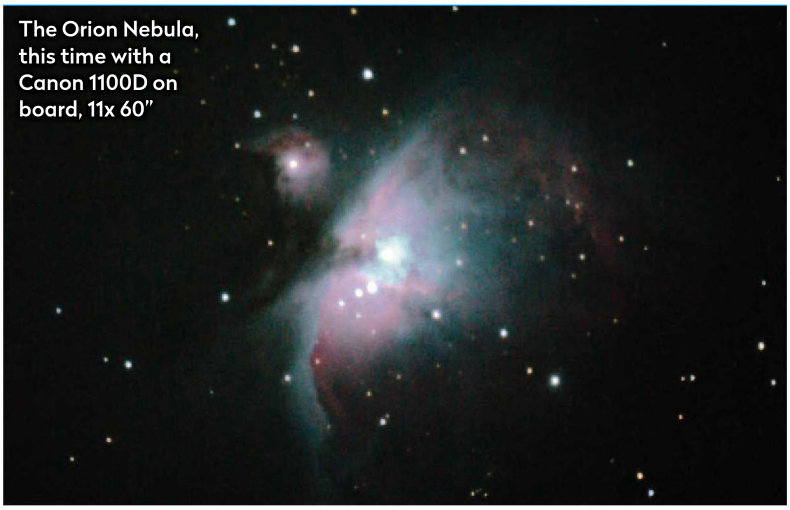
◀ A sharp, clear Moon taken with a Fairphone 4 mounted on the included smartphone holder

▼ Paired with a ZWO ASI120MC, we got nice contrast and drama in this crescent Moon (800-frame video, best 75 per cent)



Again with the ASI120MC, it did a decent job of Jupiter and the Galilean moons





The Orion Nebula, this time with a Canon 1100D on board, 11x 60"

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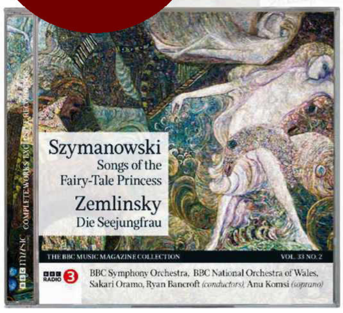
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Charlotte Daniels rounds up the latest astronomical accessories

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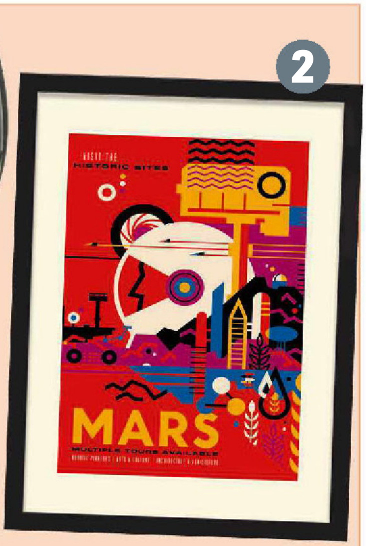
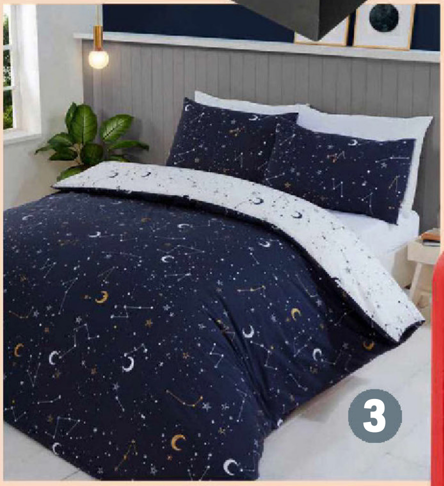
1
ASTRO ESSENTIALS





1 Astro Essentials Canon EF lens to T2 adaptor for CMOS/CCD cameras

Price £59 • **Supplier** First Light Optics
www.firstlightoptics.com

Helping make the best use of your astro equipment, this aluminium adaptor allows you to combine Canon EF lenses with a CMOS or CCD imaging camera for widefield images that don't require a new telescope.

2 Framed Mars tour poster

Price from £40 • **Supplier** Yorks Framing
www.yorksframing.co.uk

This striking framed poster is an abstract nod to space exploration past and (potentially!) future. Printed on lustre paper and in a slim modern frame, it would make an eye-catching addition to any space-lover's room. Available in A4 or A3 sizes.

3 Celestial metallic duvet set

Price from £14.99 • **Supplier** The Range
www.therange.co.uk

This reversible duvet cover set is available in single, double and king sizes, and features a navy blue celestial design on one side and white on the other. Metallic detailing is dotted throughout to elevate the constellation prints, with golden Moons and stars adding subtle shimmer. Pillow cases included.

4 ZWO CAA camera rotator

Price £299 • **Supplier** Rother Valley Optics
www.rothervalleyoptics.co.uk

This new ZWO product lets you rotate your camera and streamline the often fiddly process of framing astrophotography targets. Weighing less than half a kilogram, it's an ultra-portable accessory for deep-sky imagers who travel. ASiair and ASCOM compatible.

5 Royal Selangor orbit pewter music carousel

Price £89 • **Supplier** Farrar & Tanner
www.farrar-tanner.co.uk

This unique trinket measures 105mm x 110mm and features a Saturnesque planet with a tiny moon on the outer ring. When wound, the rings rotate and a charming tune plays, making this a sweet gift to commemorate birthdays or perhaps christenings.

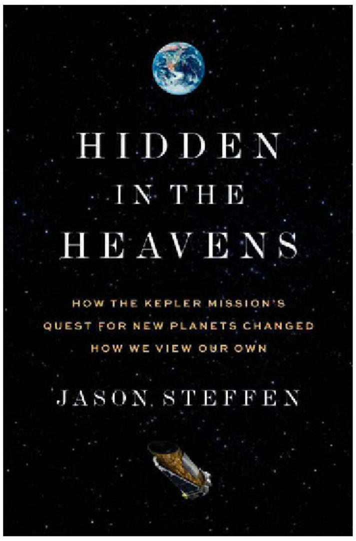
6 Manfrotto Genie micro

Price £70 • **Supplier** Wex Photo & Video
www.wexphotovideo.com

Acting as an all-in-one smart remote for your DSLR or mirrorless camera, the Genie allows you to control all capture settings from your smartphone via the Syrp app. Connect via Bluetooth or Wi-Fi to control ISO, aperture and shutter speeds from a distance.

New astronomy and space titles reviewed

BOOKS


HIDDEN IN THE HEAVENS
HOW THE KEPLER MISSION'S QUEST FOR NEW PLANETS CHANGED HOW WE VIEW OUR OWN
JASON STEFFEN

Hidden in the Heavens

Jason Steffen
Princeton University Press
£25 ● HB

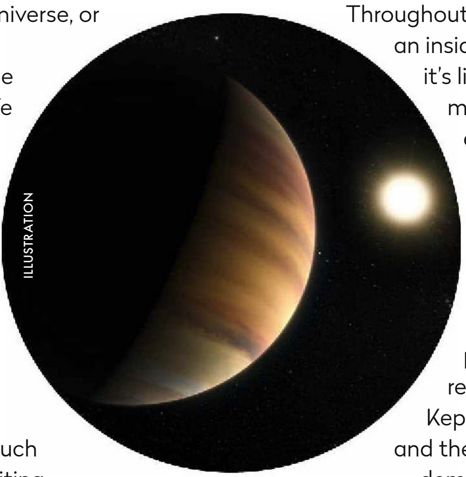
Arthur C Clarke once said of life beyond Earth that "two possibilities exist: either we are alone in the Universe, or we are not. Both are equally terrifying." The prospect of finding life beyond Earth is one that captivates humankind, driving much research into the detection and study of planets around other stars. This year marks 30 years since the discovery of 51 Pegasi b, the first such 'exoplanet' found orbiting a Sun-like star. Over the last three decades, improved technologies and techniques have accelerated discoveries and today there are over 5,800 confirmed exoplanets. For around half of these we have a single mission to thank for their discovery: the Kepler space telescope. Launched in 2009, Kepler identified planets via the transit method: it stared at a region of the Milky Way and monitored 150,000 stars simultaneously, looking for dips in their brightness that might indicate the passage of a planet in front of them. Results from this mission showed us that billions of planets populate our Galaxy, and many could be promising places to find life.

This formidable mission is the subject of *Hidden in the Heavens*. Author Jason Steffen, part of the Kepler science team, sets the scene with an account of his own personal introduction to Kepler and an overview of the mission's design, before presenting the mission's findings with clear explanations of how interpretations were made from the data collected. He describes many of the unexpected and seemingly impossible planetary systems (planets that orbit their stars in a single day spring to mind). The final chapters describe the mission's end and put the results it generated into the context of current and upcoming missions that will study exoplanets.

Throughout, we are treated to an insider's view of what it's like to work on such a mission, and by the end of this book I was in awe of both the technical and scientific achievements of Kepler – for example, the pinpoint accuracy required to maintain Kepler's constant view and the ingenuity demonstrated by the scientists processing incoming data.

A compelling read for anyone interested in Kepler, exoplanets or, indeed, a career working on space missions. ★★★★★

***Penny Wozniakiewicz** is a planetary scientist at the University of Kent*



51 Pegasi b, the first exoplanet orbiting a Sun-like star, was found 30 years ago

ESO/M. KORNMESSER/NICK RISINGER

Interview with the author
Jason Steffen

How important was Kepler?

It was central to our current understanding of distant planetary systems. Before Kepler, we knew primarily about 'hot Jupiters': large planets on short orbital periods. We had a few long-period giant planets in our catalogues and about half a dozen Neptune-sized planets. Kepler opened the floodgates. Moreover, it moved us past the initial frenzy of discoveries, where we were focused on individual systems, to a more systematic investigation where we could make population-wide statements about exoplanets.

What future missions are you excited about?

I'm looking forward to the Plato mission from ESA. That will reveal a lot of new planetary systems that we can study and is similar to Kepler in what it will find. The Nancy Grace Roman telescope from NASA will be able to find planets in really young systems. That will tell us a lot about the changes that occur in planetary systems as they age.

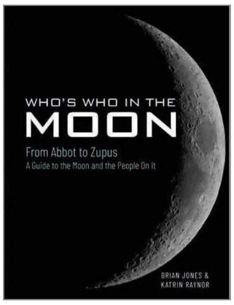
What is Kepler's legacy?

It was the first large-scale survey capable of finding Earth-like planets in Earth-like orbits. It gave us a better ability to compare our Solar System to other systems: how we're similar and how we're different. Beyond exoplanets, it allowed us to study the interiors of a wide variety of stars by looking at how they shake, which shows up in how bright they appear. It broke new ground in the kinds of planets we could see and follow-up studies we could do. It put exoplanetary science on a solid footing.

***Jason Steffen** is associate professor of physics at the University of Nevada*

Who's Who in the Moon

Brian Jones and Katrin Raynor
White Owl
£25 ● HB



The Moon is so easy to see, it can almost be taken for granted. We forget how much science, history and art is wrapped up in our local satellite. With the help of this book, however, all can be discovered.

The opening essays tell us of this book's origins, starting with BAA member Mary Evershed's 1938 publication which listed and described all the astronomers who had lunar formations named after them. We then learn about the history of these names, how and when they were chosen and how new names have been added since, including names for several formations on the far side of the Moon that were added after pictures were sent back by the 1959 Soviet Luna 3 probe. We also learn about lunar myths from around the world, and how to observe and sketch the Moon, all of which will motivate any reader, however experienced, to go out and look up.

The biographical sketches themselves are arranged by area, so the reader can get acquainted with a section of the Moon at a time and simultaneously learn about key characters from the history of astronomy. If I could offer a single improvement, it would be to have the biographies linked, to make the individuals easier to remember, but that is a minor point.

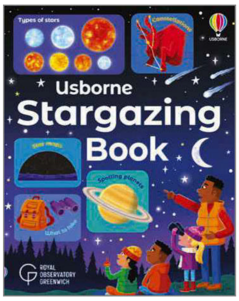
In short, I loved this book! It offers an excellent introduction to a very easily observable celestial body, while at the same time telling the stories of centuries' worth of history of astronomy. ★★★★★

***Emily Winterburn** is a science historian and writer*

Usborne Stargazing Book

GREAT FOR KIDS

Sam Smith and Lee Cosgrove
Usborne
£7.99 ● PB



How do you learn about the night sky when you're a child living in a city, looking past the streetlamps to the stars, and no one around you knows their North Star from Orion's Belt? Thankfully, there are lots of ways to teach yourself now, from star apps to YouTube – but nothing quite beats a book with lovely pictures and simple star maps. The *Usborne Stargazing Book* is one I'd have loved when I was seven years old. Indeed, I loved it now.

It's extremely simple, as you might expect for a guide aimed at ages six years and up. And it covers the absolute basics, from what to wear and take stargazing, to why the stars change their positions over the course of the night, to how to find and identify constellations.

Illustrations in a warm night-sky colour palette and lively snippets of text engage and inform. It's eminently practical in a way kids will understand. The constellations are explained as being like "dot-to-dot pictures" and an illustration of a kid holding a fist to the sky helps show how to measure 10 degrees of the sky and star-hop.

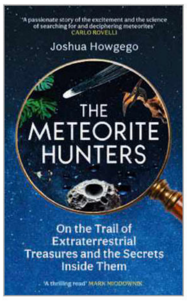
But within its concise pages it also manages to get in a bit of Greek mythology – two sentences to sum up the origin story of each constellation name – and different types of star, from white dwarf to red hypergiant.

Enticing as it is, without a friendly guide, the vast night sky may seem daunting for young children, and this is a lovely introduction for the inexperienced to enjoying the stars. ★★★★★

***Shaoni Bhattacharya** is a science writer and editor*

The Meteorite Hunters

Joshua Howgego
Oneworld
£18.99 ● HB


'A passionate story of the excitement and the science of searching for and deciphering meteorites' CARLO ROVELLI
Joshua Howgego
THE METEORITE HUNTERS
On the Trail of Extraterrestrial Treasures and the Secrets Inside Them
'A thrilling read' MARK MIODOWNIK

Have you ever watched a meteor shower? Scientists calculate that roughly six tonnes of micrometeorites fall to Earth every day. Approximately 17,600 larger meteorites (that means anything weighing more than 50 grams) land on our planet each year and there are over 73,000 specimens of space rocks held in collections worldwide.

Where these space rocks come from, how scientists go about finding them and what they can tell us about our Solar System's formation and evolution – is the fascinating story told here, taking the reader from the pyramids of ancient Egypt to the very latest space missions.

The first half of the book deals with the intrepid hunters who track down these treasures across the globe and the analytic methods they use: those hunting for fragments of historic meteorites (called 'finds') and those rapid-response meteor chasers tracing the paths of a meteorite's descent to discover the 'fall'. It's an exciting adventure story, full of characters going on wild expeditions, from the Sahara Desert to the Antarctic. It includes theft, skullduggery and being thrown into jail in distant lands.

The second half of the book drills down into the science of meteorites, how they are analysed and what the study of space rocks can tell us about their origins. Even the confusing and often contradictory theories of where Earth's water, and possibly life, came from are clearly explained. Howgego takes in the very latest research from spacecraft sample-return missions that are bringing pieces of asteroids back to Earth, and looks forward to future missions.

This is an exciting, well-written and engaging book for anyone who wants to know more about those shooting stars streaking across our skies. ★★★★★

***Jenny Winder** is an astronomy writer and broadcaster*

Anita Chandran talks to Dr Scott Sandford

Q&A WITH AN ASTEROID ASTROBIOLOGIST

The secret of how life started on Earth could lie in a sample brought back from the asteroid Bennu by NASA's OSIRIS-REx mission in 2023

What is Bennu?
Bennu is a 'rubble pile' asteroid, almost spherical in shape but with a bulging belt. It's about half a kilometre wide. It's formed from reassembled fragments from a parent asteroid that was disrupted by an impact in the early Solar System. The pieces would have flown all over the place, reassembling into bodies like Bennu. Fortunately, Bennu's orbit brings it close to Earth, so we could more easily venture there to get a sample.

▲ NASA sample return capsule science lead Scott Sandford (left) shortly after the capsule landed on 24 September 2023

KEEGAN BARBER/NASA

What exactly was the OSIRIS-REx mission?
It was a sample-return mission. We sent a probe to Bennu to collect a sample that was brought back to Earth. These missions are challenging and complex but have amazing advantages. For example, when you get a sample back, you can study it with any instrument you want, instead of just the instruments you can afford to put into space. The sample also has value in perpetuity: we're still learning things about the Moon from the Apollo samples collected 60 years ago. We ultimately brought back 121.6g from Bennu, just over twice our mission goal of 60g.

What did you discover on Bennu?
Based on previous measurements of Bennu, we were confident that we'd find some organic compounds. From analysing the sample, we found not only that there were organic compounds present, but complex molecules like amino acids that are particularly interesting for modern biochemistry, in terms of whether compounds being delivered by an object like Bennu could have played a role in getting life started on Earth.

What could these samples have told us about life on Earth?
We knew that complex organic molecules exist out in space because of observations of certain meteorites. The sample from Bennu was interesting because of the 'chirality' or 'handedness' of the amino acids. If you hold up your hands in front of you, you'll see that both hands are made up of the same features – palm, thumb, fingers – but your hands aren't identical; they have thumbs on opposite sides. Amino acids share this same property and can come in right- and left-handed versions.

On Earth, life has chosen to use only left-handed amino acids. However, if you make amino acids in a chemical process where life isn't involved, then left- and right-handed molecules are usually made in equal proportions. Looking at the chirality of amino acids in our sample, we can infer something about whether the selection of left-handed amino acids for life happened in the early Solar System on asteroids, or here on Earth.

All our measurements of the Bennu sample show equal proportions of both right- and left-handed amino acids, which is an interesting puzzle, because some of the evidence from meteorites does appear to show a larger fraction of left-handed molecules.

Do your findings suggest that asteroids brought water and organic materials to Earth?
Absolutely. The samples we got back from Bennu convincingly demonstrate that a significant fraction of this material is organic and chemically complex. We also detected all five of the nucleobases – the chemical building blocks of DNA – in the sample from Bennu. If you want to think of life on Earth as being an elaborate Lego castle, we've demonstrated that Lego pieces can fall out of the sky.

Scott Sandford is a research scientist from NASA's Ames Research Center who researches meteorites, astrochemistry and astrobiology

What else can the samples tell us?
We knew that water must have played a big role on Bennu's parent body because we see a lot of clay minerals on Bennu, which were made in the presence of liquid water. We also discovered structures called evaporites, which are minerals formed from liquid brines as the water dries up. If your house has hard water, you can see this sort of process for yourself as minerals build up on the faucet of a bathtub.

Some meteorites may have these evaporites in them as well, but they dissolve away in rain and water on Earth's surface. The Bennu samples are the first time we've been able to see a complete sequence of evaporites from an asteroid.

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Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 159 August 2018

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

April means basking in our Galaxy's riches and the welcome return of four planets to Southern skies

When to use this chart

1 Apr 00:00 AEDT (31 Mar, 13:00 UT)
15 Apr 23:00 AEST (13:00 UT)
30 Apr 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

APRIL HIGHLIGHTS

Four planets that were in conjunction with the Sun and invisible last month now return to the eastern predawn sky. Brilliant Venus is by far the brightest, with Saturn 8° to the right, shining at first magnitude. At a similar brightness is Mercury, 2° below Saturn. Neptune (needing a telescope to view) rises from below Mercury and they pass on 17th, only 0.6° apart. On 25th, a thin crescent Moon has an impressive conjunction with Venus and Saturn, forming an isosceles triangle.

STARS AND CONSTELLATIONS

In April, our magnificent Milky Way is seen edge-on, with its many open star clusters and nebulae residing in the plane of our Galaxy. In contrast, to the north is the realm of distant galaxies. Common to both regions, scattered across the sky are globular star clusters, which are distributed in a sphere centred on our galactic core. You might say stars are common to both too, but most naked-eye examples are solar neighbours, only a couple of hundred lightyears away.

THE PLANETS

Uranus is poorly placed, setting around the end of twilight mid-month. It's followed by another denizen of the outer Solar System, Jupiter, which spends April inside the horns of Taurus, not far from Aldebaran. Get onto Jupiter early, as it will be setting around 21:00. Mars is a more leisurely target, being near the meridian at sunset and departing around midnight. There's no further planetary action until Venus, Saturn, Mercury and Neptune are visible low in the predawn sky.

DEEP-SKY OBJECTS

This month, a trip to Hydra. Near its border with Centaurus lies the spectacular galaxy M83 or NGC 5236 (RA 13h 37.0m, dec. –29° 52'). Even a 60mm scope shows this seventh-magnitude barred spiral's distinctive bright core with a 5-arcminute long bar, surrounded by a 14-arcsecond halo. Larger scopes show this to be mottled; 200mm will reveal spiral arms curving off the ends of the bar in an anticlockwise direction.

Heading westward, Hydra presents another gem: NGC 3242, aka the Ghost of Jupiter Nebula (RA 10h 24.8m, dec. –18° 39'). This seventh-magnitude pale-blue planetary gets its name from being around the same size as the planet Jupiter, at 30 x 38 arcseconds. Its obvious disc has a fuzzy edge, with an 11th-magnitude central star. If the seeing is good, look for a dark gap surrounding this star.

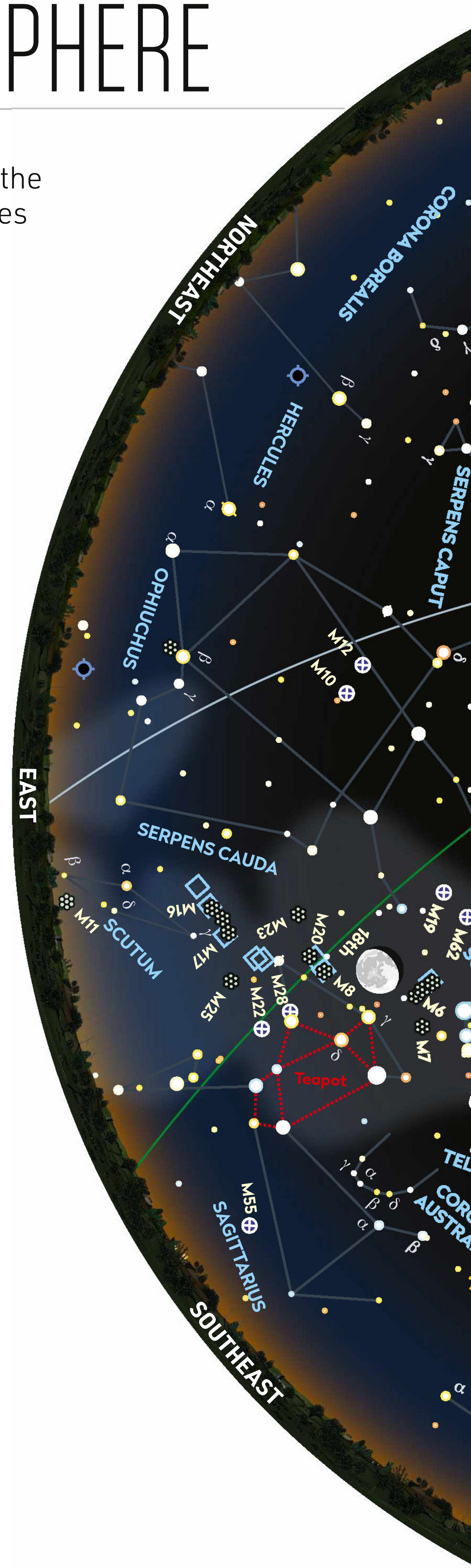
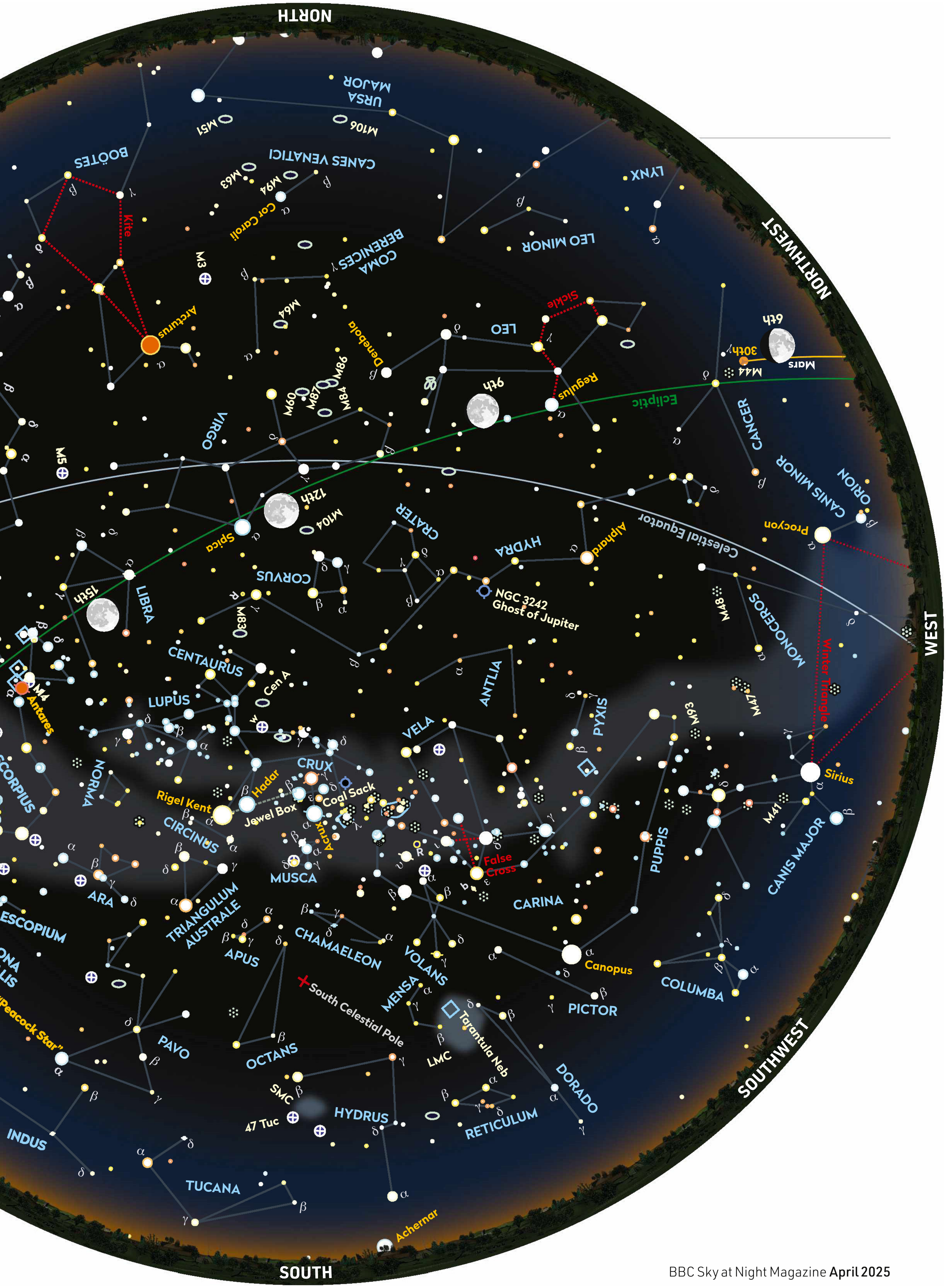


Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET

STAR BRIGHTNESS:
● MAG. 0 & BRIGHTER
● MAG. +1
● MAG. +2
● MAG. +3
● MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
URSA MAJOR
M51
M106
CANES VENATICI
BOÖTES
M63
M94
Cor Caroli
Kite
M3
COMA BERENICES
LYNX
LEO MINOR
NORTHWEST
Sickle
LEO
Arcturus
M64
Denebola
6th
30th
Mars
M44
Regulus
9th
Ecliptic
M60
M87
M84
M86
VIRGO
CANCER
CANIS MINOR
ORION
M5
12th
M104
CRATER
Celestial Equator
Procyon
Spica
Alphard
HYDRA
CORVUS
15th
LIBRA
NGC 3242
Ghost of Jupiter
M83
M48
MONOCEROS
WEST
Winter Triangle
CENTAURUS
Cen A
M4
Antares
ANTLIA
LUPUS
PYXIS
M47
M93
VELA
CRUX
Hadar
Coal Sack
Rigel Kent
Jewel Box
Acrux
NORMA
CORPIUS
CIRCINUS
Sirius
M41
False Cross
PUPPIS
CANIS MAJOR
MUSCA
ARA
CARINA
ESCOPIUM
TRIANGULUM AUSTRALE
CHAMAELEON
APUS
VOLANS
Canopus
COLUMBA
ONA
LIS
South Celestial Pole
MENSA
PICTOR
“Peacock Star”
Tarantula Neb
LMC
PAVO
OCTANS
DORADO
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47 Tuc
HYDRUS
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INDUS
TUCANA
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